1965

How to Spray and Dust

Air Applicator Institute

HOW TO

SPRAY & DUST

Air Applicator

INFORMATION SERIES

Vol. 3

HOW TO
SPRAY & DUST

COMPILED AND EDITED
BY

THE AIR APPLICATOR INSTITUTE

REPRINTED 1965

PUBLISHED
BY

AGRICULTURAL AVIATION ACADEMY

DOUGLAS COUNTY AIRPORT

MINDEN, NEVADA

What this book is about

This volume has been prepared especially for pilots, crew chiefs and others who wish to familiarize themselves with the general methods of applicating. Much of the information is of particular concern to those responsible for the application, methods of handling and precautions.

Every pilot and crew chief needs a broad general knowledge, of chemicals, pests and crops. Such persons are urged, therefore, to obtain all of the books in this series. Applicators will do a better job of applying if their knowwledge of the *entire field* of air application is both broad and accurate.

The Air-Applicator Institute wishes to thank the many persons and organizations which have so generously and freely contributed the information presented in this volume. The enthusiastic cooperation of everyone interested in air-application has been most gratifying. Full and grateful recognition is given the following persons and organizations for their work in The Air-Applicator and to the others whose contributions may have bee inadvertently overlooked.

Sharples Chemicals Incorporated; W. A. Cleary Corporation; Du Pont Chemical Company; Monsanto Chemical Company; Clair A. Brown, Q. L. Holdeman, E. S. Hagood, Louisiana State University; Alden S. Crafts, W. A. Harvey, Norman B. Akesson, A. E. Michelbacker, Ralph R. Parks, University of California; V. H. Freed, Rex Warren, LeRoy Childs, R. H. Robinson, Oregon State College; E. J. Kreizinger, State College of Washington; Robert L. Warden, James L. Krall, V. C. Hubbard, A. J. M. Johnson, Montana State College; E. P. Sylwester, A. L.. Blake, D. W. Staniforth, Iowa State College; A. W. A. Brown, University of Western Ontario; Arthur Geiser, U. S. Department of Agriculture; Lyle A. Derschieid and L. M. Stahler, South Dakota State College; R. S. Dunham, R. F. Crim and H. G. Hegeness, University of Minnesota; E. C. Decker, J. H. Bigger, F. W. Slife, R. F. Fulleman, G. E. McKibben, W. O. Scott, University of Illinois; C. I. Seely, K. H. Klages, E. G. Schafer, University of Idaho; J. R. Eyer, R. F. Crawford, State College of New Mexico; U. S. Department of Interior; G. S. Langford, Editor of Entoma; Al Flebut, Food Machinery Corporation; R. N. Fornoff, Bell Aircraft Company; R. E. Hyde, Agair; N. E. Shafer, D. L. Klingman, J. D. Furrer, Glenn Viehmeyer, University of Nebraska.

Often the *spray materials* are blamed for not giving control of insects and diseases when actually *improper methods* of application are at fault. Poor results sometimes can be associated with a *lack of knowledge* on the part of the operator concerning the job he is trying to do. This volume will bring to your attention some of the more important elements in the method of application.

Conditions vary so widely in different geographical areas and with various crop situations that recommendations must apply to *local* and often *individual* situations only.

Effectiveness of the chemicals depends upon EFFICIENT APPLICATION:

THIS MEANS . . .

a. Alert and skillful pilots.

b. Efficient equipment.

c. Accurate distribution.

d. Proper dosages.

e. Exact timing.

f. Favorable weather.

Unless you are a practicing entomologist or plant specialist you should call in outside advice to assure yourself that you have properly analyzed the situation and are using the right material and dosage. The small additional cost of obtaining expert advice to verify your own opinions is a sound investment for *your* reputation is at stake. Consult your county agent, State Agricultural college staff, State Entomologist, United States Agriculture Experiment Station personnel, and representatives of commercial chemical companies. These services are free. There are now available in some areas practicing commercial entomologists and plant specialists with whom you can consult for reasonable fees.

Here are some of the sources of information:

(a) Consult frequently with your *county agent*, *farm advisor* or *commissioner of agriculture* concerning spraying and dusting programs. They will have the latest recommendations and best information.

(b) The *publications* of the state university and agricultural colleges will be available through them.

(c) The *state bureau of chemistry* or other agency handling this interest can advise you on the latest chemicals, their uses and characteristics.

(d) Study the *literature* of the commercial chemical manufacturers.

(e) Utilize your *local library*. Ask for materials listed under insecticides, herbicides, fungicides, weeds, insects, crop pests, and horticulture.

(f) See Volume Six of this series for a classified bibliography.

PART ONE

TIMING

Crops and weeds alike are most easily injured when they are growing rapidly. Rate of growth of weeds is the most important factor in getting a good kill. Dusty, dry weeds are much harder to kill than clean, succulent, fresh and actively growing weeds. This means that the ideal situation is to catch the weeds in a fast growing condition when the crop is less succulent. Too often both the crop and the weeds are growing simultaneously. Nevertheless you should know this basic fact on optimum weed kill. 149

The utmost care in selecting the most suitable spray material will avail little, and results from its use will be disappointing, if the application is faulty. The spray boom and the venturi of the duster are not magic wands. They must be manipulated in such a manner and at such a time that thorough coatings of poison will be produced where they are most needed, and when they will do the most good.

Time and manner of application are fully as important as choice of materials. This is especially true of insect pests and diseases of agricultural crops, where the *susceptible* stage of the pest may be of short duration, and where it may be important to reach well-hidden fruits, or the under sides of leaves. Many expehiment stations publish elaborate spray calendars and some supplement these with special notices regarding the exact timing of necessary applications to important crops. The failure of users to approach the results in experiment station bulletins is due in most cases to failure in the *art of applying* the recommended measures. 100

Generally speaking, the time to get the best weed kill then is when the weed is enjoying the best growing conditions. This means good soil moisture. When the weed plant is dry it thickens up the plant waxes and it is less susceptible to the toxic action of the 2,4-D or other herbicide. The crop is the other factor in choosing the time of treatment. Many plants cannot be treated while the foliage is too young and tender. Likewise some plants ought not to be treated during certain stages. For example, wheat must not be sprayed during the boot stage.

Why Accurate Timing?

Why accurate timing? (a) It is necessary to time the use of sprays and dusts so that *insects* or *disease* organisms are affected during their most *susceptible* stage, or before extensive *damage* occurs.

◊ Fig. 1. Courtesy United States Department of Agriculture Forest Grove Experiment Station

Experimental plane of the Forest Grove station making a test run to check spray distribution pattern.

(b) It is necessary to know the *stage* of development of the plant or tree in order that insecticides are not applied when the tree or plant is in a stage where it is susceptible to damage.

(c) Some chemicals are likely to leave a *residue* at harvest. This leads to rejection of the crop by the processor. Care must be taken in timing sprays or dusts to insure the least amount of residue at harvest.

(d) By correctly timing the spray or dust to the best *weather* condition possible, a better spray job results. 50

Practically all annual weeds are best controlled by treating them when small and while in a soft, vigorous growth condition. Resistance increases as they approach maturity or when they are subjected to adverse growing conditions.

Most perennial weeds are best controlled by treating vigorously growing plants in the early bud to early bloom growth stages. Crop plants are said to be least susceptible to damage at these indicated periods: WINTER WHEAT, barley, oats — safest between well stooled and boot stages, and again after grain in dough. SPRING WHEAT, barley, oats — safest after 6 inches high and before boot stage, and again after grain in dough. CORN — apparently safest when between 4 and 12 inches high. (Use amine water only). FLAX — Two true leaves to pre-bud stage. (Use amine in water only).

In arid regions, low humidity and winter growing conditions may result in a type of weed growth that is difficult to kill. Spraying soon after a rain or an irrigation is recommended for best results. 135

TEMPERATURES

Air temperatures are quite important, particularly when using dinitro type sprays. They influence the effectiveness of the chemicals being applied. In general doseage rates will need to be increased when treatments are made at temperatures of less than 60°. They will need to be reduced when temperatures are over 80°. Careful study and consideration should be given to temperature condition. Some states require a record of the temperature condition on each job.

Inversion Conditions are Ideal

Temperature inversions exist often in the summer during early morning periods. Normally, the temperature of the air lowers with altitude (warm air on the ground and cold above). In an inversion condition this is reversed, the cool air is on the ground and the air gets warmer with altitude. Such a condition is conducive to the rapid settling of spray and dust particles.

A dry, warm day will tend to toughen up the tissue of a plant. Its surfaces are hard and waxes harden up to protect the plant. Droplets of spray obviously will tend to run off such a surface and little penetration is obtained. The air-applicator will consider this factor in determining the type of treatment best adapted to such a condition. Also the air-applicator must consider very carefully the temperature and humidity as it will affect the evaporating of several of the highly volatile materials such as chlordane and the ester forms of DDT.

DRIFT

Fine dust particles can be carried for long distances by air currents. In this country in recent years, dust has been carried in dust storms originating in the semi-arid plains region for a thousand miles or more. Dust from volcanoes is known to have encircled the earth. It is not surprising then that insecticidal, fungicidal, or herbicidal dusts when applied by airplane or even by ground machines will be dispersed to a certain extent to adjoining areas by air currents before settling to the ground. This is usually spoken of as drift. Drift has caused some concern in the past with certain insecticidal dusts containing arsenic. Drift did not, however, receive serious consideration until 2,4-D herbicides began to be widely used. With these, serious losses have resulted from the drift of the dust. 171

A look at Fig. 2 shows how very important it is to avoid the droplets falling below the 2 to 300 micron sizes. Drift is one of the serious problems in spraying and dusting because of the liability for damage to some crop which may be susceptible to the chemical which you are using. Small droplets remain suspended in the air for as long as an hour. For example, a 5 micron drop when dropped from a 10 foot altitude in a 3 m.p.h. wind will drift almost 4 miles. A 33 micron droplet (classed as fog) when dropped from 10 feet in a 3 m.p.h. wind will drift 400 feet. A 100 micron droplet (classed as mist), when dropped from 10 feet in a 3 m.p.h. wind will drift 48 feet. These figures vary with temperature and thermal convectional currents. From these figures it can be seen that breaking the spray into too small droplets materially increases the problems of drift.

Drift is not great when droplets can be confined to 300 microns or more in size. Note again in Fig. 2 that 300 micron droplets are carried only an approximate 10 feet while dropping a verticle distance of 10 feet in a 3 m.p.h. wind.

Effect of Thermal Air Currents

In anticipating where the material is going to go after leaving the plane it is necessary to consider drift due to winds and suspension in the air due to thermal currents. Relative to the latter it must be remembered that with temperatures of 85° or more when the sun is high there will usually be thermal currents. Little benefit results from either dusting or spraying under this condition.

This point is especially important to remember when applying 2,4-D due to the damage it can cause. 2,4-D has been known to cause damage 12 miles away with winds of only 5 m.p.h. Remember that thermal currents can carry the material up and keep it suspended in the air until it has drifted extensively.

Vapor from 2,4-D

Relatively pure salt and acid forms of 2,4-D do not ordinarily give off enough vapor to affect plant growth. Ester forms, however, do especially when the temperature is high. The ester forms should not be sprayed on weeds growing near sensitive plants. Cotton and tomatoes, for example, may be injured if a light wind carries the vapor from the treated area. Within an enclosure, such as a greenhouse, ester vapors have been known to damage sensitive vegetables several hundred feet away.

PROTECTION FROM 2,4-D INJURY

2,4-D is one of the most critical sprays because only minute amounts can injure many broad leafed crops. Examine the adjoining fields and make sure that drift is not going to do damage to an adjoining crop. If there are vulnerable crops use extra care when approaching field boundries watching wind directions and velocities accurately. The amount of cross wind which can be tolerated will depend upon the altitude at which the 2,4-D is being sprayed. Lower spray pressures and coarser droplets help to minimize drift. Cotton, peas, tomatoes, grapes beans and ornamentals are some of the plants easily injured by 2,4-D.

Only with the greatest care should 2,4-D sprays be used close to flowers, shrubbery, vegetables, or other valuable plants. Spray on days when there is little or no wind. Valuable plants can be partially protected with shields made of heavy paper, canvas, oilcloth, light wood or metal.

Severe 2,4-D injury to plants is usually apparent within a few days. Leaves become curled and the stems twisted. Plant growth may be checked, and after a week to 10 days the leaves may become discolored. Nothing can be done to save plants severely injured accidentally — once 2,4-D is on the plant it is too late. The chemical is rapidly absorbed by plant tissue. Even with a killing dose, however, the plant may not die for 2 or 3 weeks.

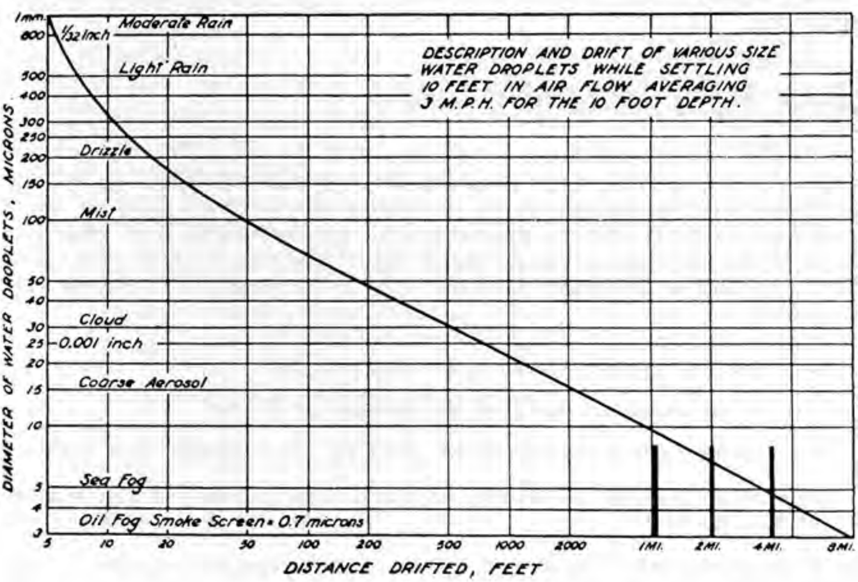
Valuable ornamental or crop plants injured accidentally by 2,4-D should not be destroyed until it is certain that the dosage was sufficient to seriously damage or kill them. Tomato and bean plants with two or three leaves deformed from slight injury have later recovered and produced an abundant crop. When several symptoms are apparent — twisted stems and deformed leaves it is usually necessary to discard the plant.

● TO MINIMIZE THE DANGER OF 2,4-D damage to nearby valuable plants, observe one or more of the following precautions:

1. Use dilute sprays of sodium and amine salts.
2. Use the lowest pressure and nozzle capacity possible for efficient spraying.
3. Use the smallest possible dosage consistent with effective weed control.
4. Spray downwind of sensitive crops.
5. Spray at the time of wear when the susceptible plants are in their least sensitive stage.
6. During and immediately following spraying cover susceptible shrubs and ornamental plants with bags (cement or fertilizer) made of treated paper or with other protective material.

These precautions are not entirely foolproof. If they cannot be followed, do not use 2,4-D weed killers near valuable sensitive plants.

Fig. 2. Chart from F. A. Brooks Courtesy Agricultural Engineering, June, 1947.



PART TWO

DISTRIBUTION

Part Two of this volume is probably the most important section of the entire information series. This volume is important because *inaccurately* calibrated airplanes and *erroneous* computing of dosage materials have often resulted in unsatisfactory jobs. Too little chemical means a starved application which is ineffective. Too much chemical may result in an injured crop. Airplane *delivery rate*, *application rate* and *pattern* are standard terminologies used extensively in the business of air-application. These terms should be correctly understood and accurately used to avoid confusion.

Pattern means the spray or dust swath, its width, the size of the droplets and their uniform distribution within the swath. *Airplane delivery rate* means the number of gallons of liquid or pounds of dust which a given airplane will deposit per acre or per minute of flying. In other words the *airplane delivery rate* refers to the volume of deposit of both the chemical and the carrier material. *Rate of application* means the amount of active chemical applied per acre (usually given in pounds or pints). Recommendations are always given in terms of the active chemical ingredient — not the total volume of chemical and carrier.

These three terms are discussed in detail in this part. See Part VI for discussion of carriers and methods of preparing chemicals for application.

Types of Computations

Careful computations are necessary, first, in the calibration of the airplane, and second, in determining the needed amounts of active ingredients and the carrier to use in loading the airplane. Each of these problems involve several mathematical computations. For example, speed of the airplane, pump pressure, size of the nozzle orfice and number of nozzles on the boom are factors in computing the airplane's rate of deposit.

Such specific questions need to be answered as:

How many acres are covered per minute of flying?

How many gallons or pounds of material are deposited per acre?

How many gallons or pounds of material are deposited per minute of flying?

What size nozzle is needed to give a desired delivery rate?

What speed must the plane be flown at with a given *pressure* and *nozzle arrangement* to give a specific delivery rate?

How many nozzles of a given size will be needed to give the required delivery rate?

In computing the amount of chemical for each plane load, the supervising chief must know such things as:

What is the airplane's rate of delivery?

How many pounds or pints of active ingredient is needed per airplane load to give the desired application rate? For example, he must be able to compute the number of pounds of a 60% dust which are needed to equal a 2 pound per acre dosage rate or how many pints of 40% triethanol amine form of 2,4-D (which contains only 24% pure 2,4-D are needed to give a desired dosage of 2 pounds per acre. He needs to know how to convert pints to pounds. These problems involve label interpretation as well as computing ability.

In this part an attempt is made to present in a simple form as possible formulas and suggestions for solving these and other problems in airplane calibration and dosage computation.

PATTERN

Deposit pattern means the *size*, the *spread* and the *uniformity* of the droplets throughout the span of the swath. The perfect spray pattern is one in which there is complete uniformity in both the number and size of droplets with an even distribution in the swath. With present equipment this goal can only be approximated and therefore every effort should be made to adjust the nozzle and boom arrangement to give maximum uniformity.

Swath width is affected by:[3]

(1) Wing span

(2) Height at which plane flys

(3) Design and power of plane

(4) Length of boom

(5) Placing of boom relative to wing

(6) Cross wind component

(7) Type of nozzle

(8) Size of droplets

(9) Turbulence

Swath Width

By effective swath is meant the width of the area receiving a uniform desirable amount of dust, spray, seed or fertilizer. The feathering out at the side of each swath must be considered and the swath runs overlappped the amount necessary to prevent stripping. Care must be used to prevent an overlap which would cause burning from an over deposit. Swaths laid too far apart will result in stripping and under dosage. Experiment with color tests until satisfied that you have an accurate check on swath width for each given airplane. Altitude of the airplane is an important factor in swath width, also the wind condition must be considered.

● 45 FOOT SWATH POPULAR: Dr. Stahler found in his survey 172 that a 45 foot swath width was most popular. "In the past years I have merited the disfavor of many aerial operators in this area by consistently arguing for a maximum spray width of 45 feet. My recent survey indicates that you are now almost universally using this swath width in your operations. Several operators indicated that they had found a 60 foot swath width entirely satisfactory in treating easy to kill annual weeds in water wheat, but that in pre-harvest treatment of wheat when these same weeds were more resistant they found it necessary to adopt a spray width of 45 feet or less. I am naturally pleased to note this swing to the more reasonable swath width and I am confident that it not only assures you a better coverage but markedly cuts the hazards of spray drift to sensitive crops and assures you of more satisfied customers."

Wind Effect on Swath

When flying directly up wind or down wind the swath pattern is affected little. A cross wind, however, tends both to diffuse the dust or spray and to broaden the swath. When laying a swath in a low velocity cross wind the cross wind is advantageous. It will tend to further disperse and down grade the peak dosages. *Strong* cross winds, however, tend to skew the deposit violently and result in a very uneven distribution. Parallel swaths are difficult to maintain under strong cross winds.

Except for drift damage (which is highly important where spraying is done in the vicinity of susceptible crops) cross winds up to 8 m.p.h. may be tolerated providing the airplane is flown at a uniform height. When changing from cross wind swaths to up and down wind swaths the *rate of deposit* will need to be changed to conform to the narrower swath and the increased or reduced ground speeds which result from the head and tail wind components.

● SWATH WIDTH EXPERIMENTS: Speaking before the Kansas Spray Conference 172 E. H. McIlvain of the United States Department of Agriculture, South Great Plains Field Station, Woodward, Oklahoma, stated "Flight spacings of 30, 45, 60, and 100 feet were tested during 1947 and 1948 when extensive studies or airplane application of various herbicides were made by the U. S. Southern Great Plains Field Station. These flight-spacing studies were made with a Stearman biplane equipped with a 30-foot boom.

There was no essential difference in the coverage and resultant kill of sand sagebrush obtained between 30- and 45-foot flight spacings when the flights were made cross-wind in a wind velocity ranging from 10 to 20 miles per hour. Strips of live sagebrush plants were clearly apparent on all plots sprayed at 60 to 100 foot intervals regardless of wind velocity or rate of application. It is, therefore, plainly evident that flight intervals of the plane should not exceed 45 feet."

● IN MARCH 1949 a comparison was made of the spray pattern from four types of spraying equipment, all mounted on Stearman biplanes. The types compared were (1) the "Standard" long boom (30 feet), with pressure pump, (2) the long boom with gravity flow, (3) the short boom (12 feet), with pressure pump, and (4) the "roto-spray" system. All planes flew 10 feet from the ground and were calibrated to apply 5 gallons per acre. The test flights were made both cross wind and *into the wind*.

The spray pattern from the two long-boom planes and from the "roto-spray" plane was about 65 feet wide or 30 feet wider and more uniform than the pattern from the short boom plane. The droplet size was least uniform from the gravity-flow plane. Although the spray pattern from the long-boom and "roto-spray" planes measured over 60 feet in width, distinct strips of live plants resulted when 60 foot flight intervals were used on sand sagebrush. This indicates the inadvisability of determining proper swath width by mere measurement of spray pattern as recorded on paper tape. 172

Significance of Droplet Size

The size of the droplets is very important in using liquid insecticides, drop size affects *penetration, coverage* and *drift*. For special purposes sprays of small particle size have very definite advantages. However, even slight wind currents may keep them from reaching the weeds or insects or carry them outside the treated field. See Fig. 3. Also very small droplets may not impinage upon plant or insect surfaces and may even evaporate before reaching their target. Large droplets are much more easily controlled and tend to penetrate dense foliage better. However, they are more wasteful of materials, may burn or otherwise injure foliage, or not give uniform or complete coverage. 41

● DROPLET SIZE AND EVAPORATION: Optimum droplet size is important. Droplets smaller than 30 microns diameter do not deposit well on foliage and insects. For ground application a mass average drop diameter of 35 to 75 microns is optimum. In aerial application, a mass average drop diameter of 60 to 80 microns is about right for crops. Forest treatment will require much larger drops because of flight altitude and drift factors.

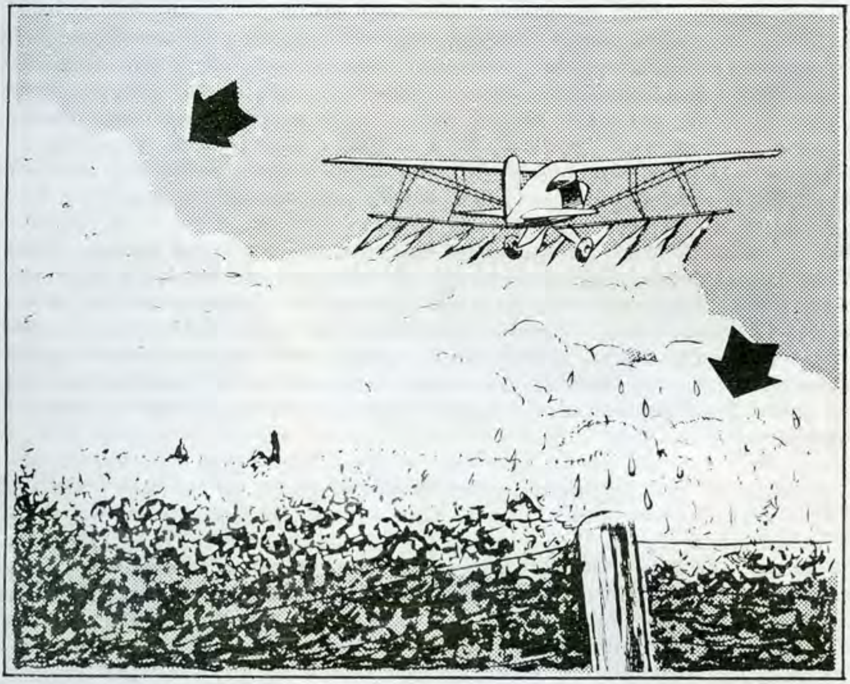


Fig. 3. Minute droplets may drift for miles in thermal currents or wind.

If a mixture consisting entirely of water or other volatile liquid and powdered insecticide is drifted in finely atomized form, the liquid may disappear before reaching the plants, thus leaving behind the dry powder or dust. Therefore, where it is necessary to apply fine mists more than approximately 15 feet it is advisable to include as much as half pint of non-volatile, non-drying liquid per gallon of mixture or 2.5 to 4 ounces of the non-volatile liquid per pound of solids in the mixture. Oils, dissolved casein, and certain hygroscopic compounds like glycerine or diethylene glycol are compounds that may be used for this purpose. A proportion commonly employed is one ounce of mineral oil and 3 ounces of adhesive semi-drying oil, such as soybean, corn, cottonseed, linseed, or fish oil, per pound of solids in the mixture.

● DROPLET SIZES IN MICRONS vs. VOLUME OF DEPOSIT: It is easy to inadvertently carry an error in thinking on this matter of drop size as compared to volume of deposit. Microns refer to the diameter of the drop. When evaluating droplet size and amount of deposit it must be remembered that the difference in volume deposit of a 500 micron drop is not five times (5 to 1) that of a 100 micron drop but 125 times or a 125 to 1 ratio. See Vol. IV for further discussion under pressures.

AIRPLANE DELIVERY RATE

Rate of delivery refers to the number of gallons of liquid material or pounds of dust which a particular airplane will deliver to each acre of ground. The air-applicator must know accurately the delivery rate for each individual airplane. Without this knowledge he cannot compute the amount of chemical or concentrate necessary to mix so that each load will carry the desired dosage.

In the designing, checking and calibrating of equipment, several computations are needed. The following are sample formulas and problems. There are other methods, short cuts, and formulas. These however, have been selected as the simplest and best methods.

Rate of Delivery Factors

The design features of the airplane which determine the number of gallons of liquid delivered per acre are:

(1) Ground speed — the faster the airplane flies the less the deposit will be.

(2) Pump pressure — the higher the pressure the greater the deposit.

(3) Number of nozzles on the boom — the greater the number or closer the spray nozzles the greater the deposit.

(4) Size of nozzle orifice — the larger the orifice the greater the deposit. See Fig. 4

Varying any *one* of these four factors will vary the number of gallons delivered per acre. Varying the *pump pressure* is not a desirable way of changing the delivery rate for if you increase the *pressure* you lessen the *droplet* size and thus increase the drift hazard. Varying the *cruising speed* is not a desirable method of controlling the delivery rate as speed variations ought to be reserved for the purpose of compensation when flying up-wind and down-wind. Varying the *number of nozzles* is possible if extra nozzle fittings exist, however, this method requires considerable time and labor. Varying the *size of the nozzle* *orifice* is the standard method of controlling the volume output. It is the easiest method of meeting different spray requirements. Rate of delivery can be varied over wide limits in this manner.

Some of the desired deposit rates in gallons per minute for various application rates for three swath widths and three flight speeds are listed in the table Fig. 5. If it is desired to spray a 40 foot swath at 3 gallons per acre using a plane with a flight speed of 60 miles per hour, the table indicates that the nozzles must spray 14.5 gallons per minute on the treated swath during the flight.

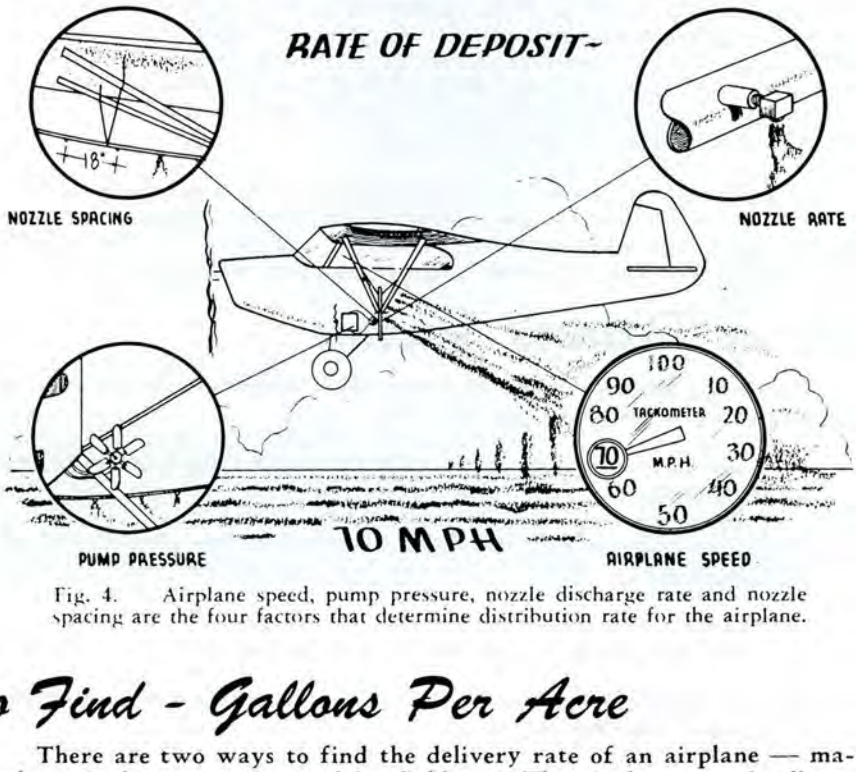


Fig. 4. Airplane speed, pump pressure, nozzle discharge rate and nozzle spacing are the four factors that determine distribution rate for the airplane.

To Find - Gallons Per Acre

There are two ways to find the delivery rate of an airplane — mathematical computation and by field test. The airplane may be flown over a known distance. This distance with the known swath width and measured amount of liquid dispersed will give the rate of delivery for the specific speed and pressure used.

The mathematical method of computing the delivery rate requires consideration of the factors previously mentioned. The airplane flies over the ground at a set speed, with a set pressure, and with a certain size and number of nozzles. The mathematical formula then must take into consideration (a) speed, (b) swath, (c) pump pressure, (d) nozzle rating. Example: How many gallons per acre would be delivered if the airplane were flown at 70 m.p.h. with nozzles spaced at 18 inches (1.67 feet) intervals and rated to deliver 1.169 gallons per minute? The three factors from which the amount of liquid delivered per acre can be determined are: (Swath width and number of nozzles can be combined into nozzle spacing). (Nozzle rate combines orifice size and pump pressure.

Speed 70 m.p.h.
Nozzle rate 1.169 gallons per minute
Nozzle spacing 1.67

These figures cannot be combined until they are converted to common units. The feet must be converted to acres and the minutes to hours. Because the answer is to be in gallons per acre we must convert the 70 m.p.h. to acres covered per hour. This is accomplished by multiplying 70 (m.p.h.) by 5280 (feet per mile) or 369,600 feet (linear distance is then changed to equivalent area by dividing 369,000 (feet) by 43,560 (number of square feet per acre) or 8.45 acres which is the area covered were the nozzle spacings 12 inches. However, with the 18 inch (1.67 feet) nozzle spacing, the area covered in one hour would be 8.45 x 1.67 or 12.11 acres.

The next step is to divide 1.169 (gallons per minute rate of nozzle flow) by 14.11 (acres covered per hour). But first gallons per minute must be converted to gallons per hour. This is accomplished by simply multiplying 1.169 by 60 which equals 70.15 gallons per hour. Next divide 70.15 (gallons per hour nozzle rating) by 14.11 (number of acres covered per hour). The answer is 4.98 which is the number of gallons delivered by the airplane per acre.

This mathematical process when written in a formula looks like this:

$$\frac{\text{(1.169 gallons per minute)} \times 60 \times 43{,}560}{\text{nozzle spacing (18 inches of 1.67 feet)} \times \text{ground speed } 70 \times \text{feet per mile } 5280} = 4.98 \text{ gals per acre}$$

The formula may be further simplified by combining the *minutes*, *feet per mile* and *square feet per acre*. Multiply 43560 by 60, then divide by 5280. The answer is 495. (495 becomes a constant representing a one foot wide swath flown at one m.p.h). The formula then may be written:

$$\frac{495 \times 1.169}{1.67 \times 70} \quad 4.98 \text{ gallons per acre}$$

In other words, when using the constant 495, merely multiply 495 times the *nozzle rating* (usually given in gallons per minute) and divide by the *nozzle spacing* (in feet) times the *ground speed* (in m.p.h). If the nozzle spacing is given in inches use 5940 as the constant instead of 495. This is simply 495 multiplied by 12.

Table of Spray Delivery Requirements in Gallons per Minute for Various Application Rates, Speeds, and Swath Widths

Flight Speed, Miles per Hour	Gallons per Acre	Required Spray Delivery in Gallons per Minute		
		30 ft. Swath	40 ft. Swath	50 ft. Swath
60	½	1.8	2.4	3.0
60	1	3.6	4.8	6.1
60	2	7.3	9.7	12.1
60	3	10.9	14.5	18.2
60	4	14.5	19.4	24.2
70	½	2.1	2.8	3.5
70	1	4.2	5.7	7.1
70	2	8.5	11.3	14.1
70	3	12.7	17.0	21.2
70	4	17.0	22.6	28.3
80	½	2.4	3.2	4.0
80	1	4.8	6.5	8.1
80	2	9.7	12.9	16.2
80	3	14.5	19.4	24.2
80	4	19.4	25.9	32.3

Fig. 5. Courtesy United States Department of Agriculture.

● TO FIND —

GALLONS PER ACRE OR AIRPLANE DELIVERY RATE

$$\frac{495 \text{ x g.p.m. (nozzle size)}}{\text{Nozzle spacing in feet x m.p.h}} = \text{G.P.A.}$$

(Use 5940 when nozzle spacing is in inches)

To Find - Acres Per Minute

Multiply the *effective* swath width (in feet) times the cruising speed in feet (m.p.h. x 5280) then divide by the 43560 (the number of square feet in an acre) times 60 (minutes per hour).

Example: Airplane flies an effective swath 45 feet and has a cruising speed of 70 m.p.h.

$$\frac{45 \times 70 \times 5280}{43{,}560 \times 60} = 6.46 \text{ acres per minute}$$

A short cut method of finding *number of acres covered* per minute of flying is to use the constant 20.2 (at 100 m.p.h. airplane flying 100 foot swath would cover 20.2 acres per minute. 100 x 100 x 5280 divided by 60 x 43560. The answer is 20.2 which can be used as a constant).

With this constant express the cruising speed and effective swath width as factors of one and multiply. For example: To find the acres covered per minute for an airplane flying 70 m.p.h. with an effective swath of 45 feet, multiply .70 x .45 x 20.2. The answer is 6.46, the number of acres covered per minute. Using the factor of 20.2 eliminates the converting of m.p.h. to feet per minute and the dividing of 43,560. In other words, it's merely the effective swath times the ground speed times the constant 20.2 (expressed in decimal fractions by placing a decimal point before the swath and m.p.h. figures).

● TO FIND — ACRES COVERED PER MINUTE

20.2 x swath x m.p.h. = A.P.M.

(Express swath x speed as factors of 1
For Example: 70 m.p.h. is .70)

To Find - Nozzle Size Required

To find gallons delivered pre minute per nozzle, (nozzle rating) multiply the gallons per acre (desired delivery rate) times the nozzle spacing times m.p.h. times feet per mile. Divide this figure by the number of square feet per acre times the number of minutes per hour.

For example: $$\frac{3.75 \times 1.67 \times 80 \times 5280}{43{,}560 \times 60} = \text{gallons per nozzle per minute}$$

This formula may also be simplified by combining 5280, 60, and 43560 into the constant 495. The formula then reads:

$$\frac{3.75 \times 1.67 \times 80}{495} = 1.01 \text{ gallons per minute per nozzle}$$

To Find - Nozzle Delivery Rate

In order to select the proper sized nozzle from the manufacturer's charts, it is necessary to know the *volume* which will be delivered per minute for the airplane in question. Multiply the acres (see formula 2) covered per minute by the desired rate of application. Divide this figure by the number of nozzles installed.

For example: The airplane equipped with 16 nozzles covers 5.66 acres per minute and you wish to apply 5 gallons of liquid per acre. 5.66 x 5 = 28.30 gallons, rate of delivery per minute. 28.30 divided by 16 equals 1.77 gallons per minute per nozzle.

Written in formula:

$$\frac{\text{acres per minute} \times \text{rate of deposit}}{\text{number of nozzles}} = \text{gallons per minute per nozzle}$$

● TO FIND — NOZZLE SIZE REQUIRED

$$\frac{\text{Airplane delivery rate} \times \text{nozzle spacing (in feet)} \times \text{m.p.h.}}{495} = \text{nozzle size}$$

Use 5940 if nozzle spacing is in inches.)

To Find — Nozzle Size (When acres per minute not known):

$$\frac{\text{gallons per acre to be delivered} \times \text{nozzle spacing} \times \text{m.p.h.} \times \text{feet per mile}}{\text{Square feet per acre} \times \text{minutes per hour} \times \text{inches per foot}} = \text{nozzle rate}$$

$$\frac{5 \times 20 \times 60 \times 5280}{43560 \times 60 \times 12} = 1.005$$

This formula may be simplified by combining the constants 5280, the 43560 and the 60 and 12 into 5940.

$$\frac{5 \times 20 \times 60}{5940}$$

(If the nozzle spacing is given in feet, use 495 (5940 divided by 12) as the constant.)

● TO FIND — GALLONS PER ACRE (Given acres per minute and gallons per minute): Divide the number of acres covered in one minute of flying by the number of gallons which the airplane is known to deliver per minute.

For Example: Plane covers 6 acres per minute and delivers 10 gallons per minute.

10 divided by 6 equals 1.67 gallons delivered per acre

HOW TO MAKE A FIELD TEST

1. Determine the effective width of the swath by flying at desired altitude and measuring the deposit on sensitized paper or glass squares (see elsewhere "Deposit Pattern").

2. Divide the swath width (45 feet) into 43,560 (number of square feet in an acre). The answer is the linear distance necessary for the plane to travel in order to cover one acre. $\frac{43,560}{45} = 993$ feet.

   If the airplane has an effective swath of 45 feet it will spray an acre every 993 feet of linear travel. For an adequate airplane test this is hardly enough distance. Doubling the amount to 1986 which is approximately 2000 feet it would give 2 acres of coverage and a more accurate rate of delivery test.

3. Set the pressure and the proper cruise speed to simulate actual spraying. Top the tank then fly a measured 2000 feet.

4. Measure accurately the gallons used by topping the tank again. Divide this by 2 and you will have the rate of deposit per acre.

Try this problem: Suppose you buy an airplane sprayer and wish to check its rate of delivery. You put 5 gallons of water in the spray tank and found that it took 6000 feet to exhaust the supply. You found by measuring that the spray boom was 25 feet long but from the color sheets you find that flying at a ten foot altitude the *effective* spray width is 36 feet. How many gallons per acre will be delivered?

Solution: First, divide 43,560 (square feet per acre) by 36 (swath width). This gives 1210 and is the number of linear feet which a plane with a 36 foot swath must travel to cover an acre of area. Second, divide the 6000 (distance traveled in the test) by 1210. This gives 4.95 or the number of acres covered in the test. Third, divide 5 (gallons used) by 4.95 (acres covered). This gives 1.01 (gallons deposited per acre or the airplane's rate of delivery).

● CALIBRATION CORRECTION WHEN USING OIL: Oil flows approximately 15% to 25% faster than water. If you field test with water, a correction for flowability must be made. For example, if the test run uses 3 gallons (12 quarts) of water, let 12 equal (6/5) six-fifths, then find (5/5) five-fifths by dividing 12 by 6 and multiply ing by 5. The answer, 10, is the equivalent had oil been used instead of water in the calibration.

To Determine Speed for a Ground Rig

In the case of ground rigs the tractor speed can be varied thus controlling the rate of delivery through varying the speed of the rig. The following formula will give the speed necessary for a given desired rate of delivery.

$$\frac{495 \quad \times \quad \text{gallons per minute per nozzle}}{\text{Nozzle spacing in feet} \quad \times \quad \text{gallons per acre}} = \text{m.p.h}$$

Example: 176 How fast should the sprayer be run if each nozzle delivers 0.067 gallons per minute, the nozzle spacing is 20 inches or 1.67 feet, and it is desired to spray 5 gallons per acre?

$$\frac{495 \quad \times \quad 0.067}{1.67 \quad \times \quad 5} = \frac{33.17}{8.35} = 3.98 \text{ m.p.h. tractor speed}$$

VOLUME APPLIED PER ACRE

Previously was discussed airplane *rate of delivery*. Airplane rate of delivery refers to volume. Volume means the number of gallons of liquid or dust carrier plus active chemical that is applied per acre. The amount of water, dust or oil has little significance. The right volume is that amount which will give adequate and uniform distribution on the foliage.

Low-Volume Application

The term *low-volume spray* is usually used to describe applications in the range of 5 to 20 gallons per acre, although 30 to 40 gallons may also be considered as a low-volume application. At the 5 to 20 gallon rate, a nozzle opening corresponding to a .020 to .025-inch drill size is required. These low-gallonage nozzles are most efficient at spraying pressures of 20 to 40 pounds per square inch. Volumes between 30 and 60 gallons may be applied with nozzles with openings of .032 to .046-inch diameter. Limited variation in rate of delivery of any nozzle may be obtained by changing the pressure developed by the pump and the speed of the airplane or other vehicle. Varying the orifice size, however, is the practical way. 63

● LOW-VOLUME TESTS: Quoting from the 1949 Western Weed Conference (Report on Airplane Application of Herbicides) "Many air-applicators seized upon the possibility of using low-volumes of oil rather than the much greater volumes of water needed as a carrier because of much lower application costs. Early tests by the P-T Air Service at Hays, Kansas, showed that 1 gallon of diesel fuel No. 2 per acre gave adequate coverage. That gallonage became more or less standard for most of the airplane applications. Since oil was used as the carrier by most operators, the esters of 2,4-D were used almost exclusively for airplane spraying. One to three gallons per acre is the suggested volume range for a water carrier. More may be required to penetrate dense growth such as sometimes exists in perennial weed patches. 2 to 4 quarts per acre is the preferred volume range for oil. Oil volumes in excess of 4 quarts lose whatever economic advantage they may have over water and usually increase the hazards to the crop.[147]

Because the airplane can only carry a limited pay load 600 to 1,000 pounds for fixed-wing planes and 400 - 600 pounds for helicopters—the spray mixture will need to be more concentrated or have less diluting oil or water than that applied by ground rig for the same job. For example, certain selective sprays are applied with a ground rig at 80 gallons per acre, but will be applied by plane, with the same amount of active ingredient, at only 15 to 25 gallons per acre. When heavier volumes are desired, or when there is no airport near the field to be sprayed, the charges per acre will be increased or will be made on a per-gallon basis.[3]

● LOW GALLONAGE EQUALLY EFFECTIVE: Studies made by C. I. Seely,[129] in 1945 showed that with non-selective spraying of field bindweed the kill of weeds was practically the same whether 10 gallons or 600 gallons of water were used per acre. This work was the basis for marked reductions in the volume of solution used per acre. At the time these tests were conducted the average volume per acre was probably greater than 300 gallons. Within 2 years the average had dropped to about 40 gallons per acre and some applications were being made at below 5 gallons.

In 1947, Seely and Lambert C. Erickson,[129] conducted tests at Grangeville using volumes varying from 5 to 80 gallons of water per acre in the selective spraying of winter wheat infested with corn crowfoot. They found in these tests that the kill of crowfoot was about the same regardless of volume of solution used. However, the grain seemed to be more severely stunted when smaller volumes were used in the spray solutions. This raised the question as to whether selectivity was being lost by the use of very low gallonage.

Low Volume Application of 2,4-D

Low-volume application of 2,4-D has been very successful. Following effective use of 2,4-D dusts as selective herbicides in cereals, and the application of volumes as low as 10 gallons, by plane, trials with 2,4-D solutions as low as 1 to 2 gallons per acre were successful provided distribution was even and thorough.

Where oil is used as a low-volume carrier for 2,4-D, diesel fuel and similar oils of *medium* toxicity seem satisfactory, since only one half gallon to 1 gallon per acre is required. Where oil is used in greater volume in selective spraying, an oil of low toxicity is recommended, such as automotive diesel oil.[5]

According to experiments by Erickson,[129] on the average, the amount of water had little influence on the percentage of weeds killed but did have considerable effect of the *yields* of the crops. In this study volumes of less than 20 gallons per acre reduced the yields while rates above 20 gallons per acre increased them. It was apparent from the data that with the more resistant crops such as wheat, the loss in selectivity was not as important as it was with the more *sensitive* crops such as oats and flax. Where at least 20 gallon volumes were used, there was very little drift damage to adjacent unsprayed strips and considerably less trouble from clogged nozzles. On the basis of these tests, it would seem to be desirable in selective spraying to use at least 20 gallon volumes unless lack of water makes lower volumes necessary. This statement applies especially when selective sprays are used on crops sensitive to 2,4-D. Other experiments in 1947 with low-volume sprays as low as 5 gallons per acre by ground rigs and ½ to 1½ gallons per acre by airplane showed that such low volumes are satisfactory for spraying 2,4-D. Some of the other herbicides require from 30 to 100 gallons diluent per acre.

● CONVERTING HIGH TO LOW-VOLUME EQUIPMENT: Many of the existing high volume sprayers can be adapted to low volume as follows:

1. Reduce delivery of high-volume pump by reducing revolutions per minute or by increasing by-pass volume.

2. Set pressure regulator so operating pressure does not exceed 40 pounds per square inch. Instant (diaphragm type) pressure regulator may be installed in pressure line. All calculations in the calibration table are based on 40 pounds per square inch.

3. Replace high-volume nozzles with low-volume nozzles and containing screens. (See calibration table for suggested nozzle sizes for different volumes.

4. Install line strainer in the pressure line as close to the boom as possible. This strainer should contain a 100 mesh or finer screen to protect nozzles from clogging. A strainer should be installed between the tank and pump to prevent abrasive material from entering the pump and causing excessive wear.[176]

RATE OF APPLICATION

Most formulations and concentrates contain inactive ingredients such as stickers, spreaders and emulsifiers. *Rate of application,* however, refers only to the pints or pounds of active chemical ingredient applied to each acre of ground. For example, 2,4-D may be recommended for application at the rate of 2 pounds per acre. Suppose you have available 2,4-D in 60% powder form. This means that each pound of material contains only 60% of the pure 2,4-D acid. Suppose you wish to apply 2 pounds pure acid per acre. How many pounds of the 60% powder must be used? Divide 2 by .60. 2 divided by 60 equals 3.33 pounds (3-1/3 pounds). To find: amount of pure acid divide the dosage rate by the percentage of active ingredient.

● TRY THIS PROBLEM: You wish to apply 1½ pounds per acre of given chemical which is available in a 75% powder. How many pounds of this mixture will you need to use per acre?

Always read all the directions on the chemical containers. Follow the recommendation very closely. Never overdose. This is particularly important when doing in-crop spraying.

When definite proportions of materials are indicated, the proportions should *not* be changed to make the solution stronger or weaker, unless there is a positive knowledge that such change is advisable. A weaker solution usually will be ineffective, while a stronger solution often will be injurious besides being wasteful.

When it is recommended that a substance be added to one kind of insecticide or fungicide it does not follow that the same substance can be added to another insecticide or fungicide. The use of summer oil with bordeaux, for instance, is often recommended, while the same oil used with lime-sulfur will severely burn the foliage. Finally, a fungicide or insecticide improperly prepared — the order of mixing changed or an ingredient, such as an emulsifier or a safener, omitted — may be either ineffective or injurious. Follow formula and directions strictly. It is highly important that everyone using agricultural chemicals understand fully how to read and interpret the contents figures on the labels of containers. It is also important to compute accurately the desired dosage amounts for dilution. Most container labels will give the active ingredient percentage by weight, for example, *toxaphene* 30%. The label will list the inactive ingredients which usually consist of an emulsion concentrate, one or two solvents, and an emulsifier. These may be lumped together 70%.

FOLLOW CONTAINER DIRECTIONS CAREFULLY

The label will give the weight of the gallons of active ingredients (if it is a five gallon container, weigh it and divide by five). Multiply the weight of one gallon by the percent of active ingredient. The answer is the weight of the active ingredient per gallon. Divide this by eight and the answer is the weight of active ingredient per pint. Divide this figure into the desired poundage per acre and the answer is the number of pints equivalent to the dosage in pounds.

For example:

Toxaphene 30%

Inactive ingredients 70%

Weight per gallon 8.5 pounds.

Weight of inactive ingredient equals 30% times 8 equals 2.40 lbs.

Weight of 1 pint equals 2.40 divided by 8 equals .3 lbs.

Desired rate of application 3/4 pounds per acre

Equivalent pints per acre equals (3/4 lb.) .75 divided by .3 equals 2½ pints.

This means that to get 1 gallon of oil solution of the desired dosage rate of ¾ pounds per acre, you would use 2½ pints of the commercial material and 5½ pints of oil. Because you are putting the material into solution you may find that 2½ pints of the chemical and 5½ pints of oil don't give you a gallon of solution (this is due to inter-molecular action — the interaction within the solution). Put the chemical in and fill to make a gallon or put the number of pints into the spray tank to give the 2½ pints per gallon proportion then fill the tank.

Comparing the Cost

Prices may be misleading. One material may be quoted at $2.50 per gallon, and advertised to control the same insect species as another material selling for $9.00 per gallon. However, if the first preparation must be diluted at 1 part per 100 quarts of water, 100 gallons of spray will cost $3.00 while the second, if effective at 1 part to 800 parts of water, will cost but $1.25 per 100 gallons of diluted spray.

If there are allowable differences in the rate of application, this too must be taken into consideration. It is not the cost per unit of *purchased* insecticide that counts, but the cost per unit of *treated* crop, space, or material. Furthermore, it will sometimes pay to figure the cost of ingredients of dual or triple-purpose preparations, and to purchase and add them separately to the diluted spray.100

The kind as well as the total percent of active ingredients should be noted when selecting an insecticide. While certain wetting and spreading agents, such as oils and soaps, may be counted as active ingredients, their toxicity in the diluted spray is slight in comparison to that of the primary principle or principles of contact intecticides, such as nicotine, pyrethrins, or rotenone. For certain purposes nicotine sulphate containing 40 per cent nicotine is used at 1 part to 800 parts of water. The concentration of nicotine is thus 40/800 equalling .05 per cent nicotine. Some idea of the efficiency of another nicotine preparation may be obtained, therefore, by dividing the per cent of nicotine by the dilution recommended by the manufacturer.100

When comparing the prices of competitive products first look for the content and percentage of the technical active chemical ingredients. A product that has a content consisting of a 50% technical chemical ought obviously to be much cheaper than one which contains a 90% technical chemical.

A second consideration when making price comparisons is the amount. Some labels give contents in weight and some in volume. Convert them both to weight or both to volume then compare the amounts of *active ingredient.*

COMPUTING ACID EQUIVALENTS

2,4-D is a white, crystalline, organic acid. When pure, it resembles sugar in appearance. The pure material will not dissolve in water; consequently it is necessary to treat it in manufacturing so that it may be soluble in water or so it will disperse in water. The 2,4-D is non-poisonous to either man or livestock and is not corrosive when used according to direction. It is non-inflammable.

Since the 2,4-D has to be treated to get it in usable form, certain derivatives are formed. The chemist thinks of a derivative as being the product of a reaction between the parent substance and some other material. Thus he might treat the 2,4-D and lye (sodium hydroxide) together to form the sodium salt derivative.

When two materials are mixed together, one of which is not active, it can readily be seen that the mixture, weight for weight, will not be equal to the "active" material. Rather it will contain a certain percentage or equivalents of the "active" material. So it is that when a

NEVER COMPROMISE ON ACCURACY

★ ★

COMPROMISES ON ACCURACY USUALLY RESULT IN DISSATISFIED CUSTOMERS, A LOSS OF REPUTATION AND DAMAGE CLAIMS.

derivative of 2,4-D is prepared we end up with a chemical mixture of 2,4-D that contains an equivalent of the original 2,4-D acid. The equivalent content of the m i x t u r e, weight for weight, will depend, of course, on the amount of weight of so-called inert ingredients added. There are a large number of derivatives of 2,4D all containing varying equivalents of pure acid. Some of the more common derivatives and their solubility and properties are contained in Fig. 6.

By knowing the *percentage* by *weight* of a given 2,4-D derivative commercial herbicide, the pure 2,4-D equivalent can be calculated by using the acid equivalent of the compound. Thus if a *butyl ester* of 2,4-D preparation weighs 8.25 pounds per gallon and contains 40 per cent of the active ingredient and we know that butyl ester has an acid equivalent of .8, it is possible to calculate the 2,4-D acid equivalent it contains:

8.25 x .40 x .8 = 2.64 pounds 2,4-D /gallon

Pounds times per cent of active ingredient equals acid equivalent.

INTERPRETATION OF LABELS

Considerable care must be used to understand and properly interpret the labels on 2,4-D containers in order to prepare materials accurately for the desired rate of application. For example: a label which states 40% triethanol amine of 2,4-D contains only 24% pure 2,4-D. See Fig. 6. Preparations in the *triethanol amine* form contain only 60% of the acid equivalent. (Therefore 40% x 60% equals 24% acid equivalent).

Some companies now give directly in pounds acid equivalent per gallon. Also some states require all sellers of 2,4-D to state the strength of their materials on the basis of parent 2,4-D acid content.

The containers of ester 2,4-Ds are usually labeled giving the 2,4-D content in the combined ester form. To determine the pure acid content it is necessary to know the acid content of the respective esters. The three most common are butyl, ethyl and isopropyl. To get the acid equivalent of each, multiply the butyl by 80%, the ethyl by 89% and the isopropyl by 84%. For example, a 40% butyl ester will contain 32% 2,4-D acid equivalent. (40 x 80 equals 32%).

The dusts of 2,4-D contain 5% or less of the acid equivalent. In the *acid dust* the acid content is given directly. But in the *ester dusts* the

STUDY THE LABEL
CAREFULLY

content of acid equivalent is given in the combined 2,4-D ester form and can be figured in the same manner as the previously given example.

Percentage of Pure Acid

Since there are many kinds of 2,4-D materials on the market at the present time you will need to keep the table of pure acid equivalent Fig. 7, handy: *Column One* means that the standard formulation contains that percentage of pure 2,4-D acid.121 *Column Two* means that it would take that many units of the formulation to equal 100 units of pure acid.

How to Compute Free Acid

The various formulations of 2,4-D vary both in the *chemical compound used* and in the *percentage* of 2,4-D pure or free acid.

Table I — FORMATIONS OF 2,4-D SHOWING MOLECULAR WEIGHT, AND EQUIVALENT, SOLVENT AGENT AND STATE OF MATERIAL

2,4-D derivative	Molecular Weight	Per Cent 2,4-D acid or acid equivalent	Dissolves in
2,4-D acid	220	100	Alcohol, benzene
Ammonium salt	237	93	Water
Sodium salt	242	91	Water
Sodium salt (monohydrate)	260	85	Water
Diethanolamine salt	325	68	Water
Triethanolamine salt	369	60	Water
Morpholine salt	307	72	Water
Ethyl ester	248	89	Oils, but emulsifies in water
Isopropyl ester	262	84	Oils, but emulsifies in water
Butyl ester	276	80	Oils, but emulsifies in water

Fig. 6.

Since the amount of this acid equivalent varies with the chemical compound and its per cent in a formulation, acid equivalent is used as a bisis for comparison. Thus butyl ester contains 80 per cent acid, diethanolamine salt 68 per cent acid, diethanoalmine salt 68 per cent and monohydrate sodium salt 85 per cent. But any formulation may vary in the per cent of chemical; thus one commercial ester contains 14 per cent of butyl ester and another 40 per cent. Since butyl ester contains 80 per cent acid, the first commercial product would contain 80 per cent of 14 per cent and the second 80 per cent of 40 per cent.

All recommendations for amounts of 2,4-D to use refer only to the acid equivalent. The amount of 2,4-D acid in a commercial formulation must appear on the label either directly in pounds or as a percentage of the formulations, In other words, first know the percentage of pure acid for the various types of formulations, Fig. 6, and second, know the amount of that formulation used in the commercial concentrate you are using.

PROBLEM: Your spray tank holds 80 gallons and is calibrated to deliver two gallons per acre. You wish to apply a dosage of 3 pounds per acre. The label on the 2,4-D container reads butyl ester 2,4-D dichlorophenoxyocetic acid 40% net weight per gallon 8.2 lbs. Find the

PERCENTAGE OF PURE 2,4-D IN VARIOUS FORMS

Substance (combined mixture)	Percent 2,4-D Pure Acid	Equivalent Units Required to contain 100 Units of Pure 2,4-D Acid
2,4-D Acid	100	100
2,4-D Ammonium salt	93	108
2,4-D Sodium salt (anhydrous)	91	110
2,4-D Sodium salt monohydrate	85	118
2,4-D Diethanolamine-salt	68	147
2,4-D Triethanolanoine salt	60	167
2,4-D Methyl ester	94	106
2,4-D Ethyl ester	89	112
2,4-D Propyl esters (2)	84	119
2,4-D Butyl esters (4)	80	125
2,4-D Annyl esters (15)	76	135

Fig. 7.

acid equivalent per cent? Find the weight of pure 2,4-D acid equivalent per gallon? Find the number of gallons of concentrate needed for a load.

SOLUTION: First, we turn to the table of acid equivalents for the various standard formulations (Figure 6) and find that butyl ester contains 80% 2,4-D acid. The next step is to multiply 80% times 40% (.80 x .40 equals .32) or 32 per cent. This means that 32% of the 8.2 pounds of each gallon is pure 2,4-D acid. The next step is to multiply 8.2 gallons by 32% (8.2 x .32 equals 2.62) or 2.62 pounds of pure 2,4-D in each gallon of material. The final steps in computing the amounts of concentrate needed is to divide the tank's capacity by the rate of delivery per acre. (80 divided by 2 equals 40). This will give the number of acres which can be sprayed in one load. The number of acres times the desired pounds per acre application rate will give you the total pounds required per load. (40 x 3 equals 120). Divide this figure by the pounds of pure 2,4-D per gallon of the concentrate material and you have the number of gallons of concentrate needed for the load. (120 divided by 2.61 equals 45.8) 45.8 gallons of concentrate are needed to deliver a load of butyl ester 2,4-D at the dosage rate of 3 pounds per acre.

Converting Acid Equivalent to Pounds

After determining the volume which a certain airplane will deliver per acre under constant speed and pressure it is necessary to determine how much 2,4-D acid of a given commercial product is necessary per gallon of the airplane's volume in order to deliver the correct dosage of "so many pounds per acre". Figure 7a will help to convert the content described on the label to equivalent pounds or ounces.

Percent 2,4-D ACID EQUIV. as listed on container	Lbs. of chemical for application of .1 lb. 2,4-D acid per acre*	Ounces of chemical to get .1 lb. of 2,4-D acid per acre
32%	.313	5.01
33%	.303	4.85
34%	.294	4.70
35%	.286	4.58
36%	.278	4.45
37%	.270	4.32
38%	.263	4.21
39%	.256	4.10
40%	.250	4.00
41%	.244	3.90
42%	.238	3.81
43%	.233	3.73
44%	.227	3.63

Fig. 7a.

*Pounds solution obtained by dividing "*per cent acid equivalent*" into 10. The above table applies where the acid equivalent is given on a per cent of weight basis.

EXAMPLE: To apply .3 pound 2,4-D per acre when *acid equivalent* is 37%. Refer to the line with 37 in first column. Multiply the figure .270 (in the same line) by 3 equals .810 pound (13 ounces), the amount to be mixed with any quantity of water or oil to be applied per acre.157

● COMPUTING ACID EQUIVALENTS FROM POUNDS OR PERCENTAGES: If the acid content is stated in pounds per gallon, the amount of acid in a pint can be found by dividing the pounds in a gallon by 8 (the number of pints per gallon). If the acid content is stated in per cent, multiply the per cent by the weight in pounds of a gallon of the material and divide the product by 8 to get the fractional part of a pound of acid in a pint of the material. Commercial products of 2,4-D may vary in weight from 8 to 10 pounds per gallon.

For example: If it contains 4 pounds of 2,4-D per gallon, then 1 quart will contain 1 pound of pure 2,4-D. If this is not given, then the percentage of pure 2,4-D will have to be determined and multiplied by the weight per gallon of the particular material. Example: A label might state: "Isopropyl 2,4-dichlorophenoxyacetic acid 45%. Net weight per gallon 8.6 pounds". To find the acid equivalent multiply the ester 2,4-D content by the reduction factor 84 per cent (given earlier) 64 x .84 equals 38.64. The acid equivalent is then 38.64 per cent. 38.64 x 8.6 (pounds per gallon) equals 3.32. This is the number of pounds of 2,4-D equivalent contained per gallon.164

● METHOD FOR COMPUTING (Agricultural Experiment Station, South Dakota State College: Four steps are involved in determining the amount of 2,4-D to be used in liquid form. If the net weight is given on the label, omit step 1. Steps 1 and 2 are omitted if the weight of 2,4-D acid per pint, quart or gallon is given.

Step 1 — Net Weight. If the net weight is not given on the label but the specific gravity is given, the net weight can be determined with the following formula: Specific gravity times 8.3 equals weight of 1 gallon of material times number of gallons in container equals net weight of material.

Step 2 — Determine the number of pounds of 2,4-D acid in one pint of chemical. This is done by using the net weight, the per cent of 2,4-D acid and number of pints in the container with the following formula: Per cent of 2,4-D acid x net weight divided by number of pints in container equals pounds of 2,4-D acid in one pint.

Step 3 — Determine the number of pints to be used per acre. The above mentioned chemical contains slightly over one half pound of 2,4-D acid in each pint of chemical. If 1/4 pound of 2,4-D acid is to be applied per acre, one-half pint would be enough. Approximately 1½ pints would be needed to apply ¾ pound of 2,4-D acid per acre.

Step 4 — Determine the amount of chemical needed for each sprayer load. Use the following formula: Gallons in sprayer divided by gallons per acre times number of pints per acre equals pints needed per sprayer load.

● THE AMOUNT OF A POWDERED CHEMICAL needed for each sprayer load of water can be calculated as follows:

Step 1 — Using the following formula, determine the number of pounds of chemical needed per acre: Pounds 2,4-D acid per acre divided by per cent of 2,4-D acid equals pounds of powder per are.

Step 2 — Using the following formula, determine the number of acres that one sprayer load will cover. Gallons in sprayer divided by gallons per acre equals acres per sprayer load.

Step 3 — Determine the amount of chemical needed for each sprayer load. Multiply the pounds of powder per acre (step 1) by the acres per sprayer load (step 2) in the following formula: Pounds powder per acre times acres per sprayer load equals pounds of chemical per load

● CALCULATING AMOUNTS OF DUST: The amount of 2,4-D dust required to apply a certain amount of 2,4-D acid per acre may be determined as in step 1 of the calculation for powdered chemical.265

Many errors have been made in computing 2,4-D dosages because of errors in interpretation of labels. Usually these errors have resulted in under dosage and account for the poor results often obtained.

PART THREE

GOOD APPLICATING PRACTICES

Careful organization includes provisions for crews, flagmen, loaders, loading equipment, ground transportation, and landing strips. The goal is to organize equipment and personnel to save time and expense yet do an efficient job for the grower.

Crew Chief's Responsibilities

Crew chiefs must possess a broad knowledge of all phases of application. No one can get into or stay in the air-applicating profession today who does not have the proper "know how". With a field that is as fluid and changing as air-application you need to spend a substantial portion of your time keeping abreast of new developments. Here are some suggestions which will help:

- WRITE TO THE CHEMICAL COMPANIES: (See Volume Six, Directory) Ask to be put on the mailing list of the chemical companies to receive their literature on insecticides and herbicides.

- VOLUME SIX of this series lists the best literature which is available on the various phases of agricultural aviation. These references have been carefully selected, classified and annotated. Choose from the bibliography those titles which apply directly to your work. The pilot who strives to keep up and continually broaden his knowledge of air-application is bound to progress.

- IN ALMOST ALL OF THE STATES the state universities or the state colleges of agriculture independently or in cooperation with the state departments of aeronautics, sponsor short courses or schools for air applicators. Find out from the college of agriculture or your state director of aeronautics where these schools are being held. You will profit greatly from them.

- AS THE PILOT OR CREW CHIEF responsible for the actual application you have a moral and in some cases the legal responsibility for the manner in which application is made. Be sure that you know the federal, state and county regulations governing all phases of air-application. (See Volume Five, Regulations,) of this information series for a complete list of states having regulations now in effect.

- AVERAGE SIZE SPRAY UNIT: A desirable unit is 2 airplanes, 3 pilots, 2 flagmen, a tank wagon of at least 500 gallons and a tank man.

Choosing Equipment

In selecting the most practicable and efficient type of aircraft, consideration should be given to (a) size of the field to be treated, (b) their proximity to landing strips, (c) loads to be carried, (d) elevation and type of terrain to be treated, (e) cost of operation and maintenance , and (f) adaptability of the aircraft to the installation of dispersal mechanisms. (See Volume Four for discussion and illustrations of airplane types.)

Two of the more important features in aircraft are (1) ability to take-off and land on short strips, and (2) high ratio of pay load to total weight.41 (See pictures of the FAA agricultural prototype, Ag 1 elsewhere in this series).

● LOCATION OF LANDING STRIPS: The closer the strip can be to the field being treated the less time will be wasted. Safety, however, must not be sacrificed. A smaller load from a nearby strip might prove more advisable than a heavy load from a more distant strip. Landing area safety factors are: smoothness of the surface; freedom from high grass, rocks or obstructions; firmness of surface; distance from field, desirable and gross load limits; power condition of engine; elevation; temperature and humidity.

● EFFICIENT LOADING EQUIPMENT: Often in air-application jobs, time is of the *essence*. The situation is critical. The planes ought to be in the air every available minute. Pumping and other loading equipment must be fast and efficient. The spray pump ought to be installed with provisions for its use in refilling the spray tank.

Flying the Airplane

Uniformity of application probably is the most important single application factor, and uniformity is determined by equipment and flying methods employed. Putting it another way, the pilot's objective is to distribute the uniform numbers of droplets over uniform swath widths all the way across a field. Swath width is governed by equipment, height above crop and winds. Most experienced operators fly a swath width no greater than 125 per cent of the boom length. A 36 foot boom would give a 45 foot swath. It is noteworthy here that much of the crop damage reported has been in fields flown with an extremely wide swath which resulted in uneven distribution of the spray pattern. This has been particularly true when oil was used as a carrier. The use of flagmen to insure correct flight paths is highly desirable.

● PILOT ACCURACY: The accuracy of the pilot is of extreme importance in the effectiveness of the spray job. Skipping strips results in a poor kill and a bad reputation. Overlapping results in possible crop damage through burning and wastage of materials.

● **IDENTIFICATION OF THE FIELD:** There have been occasions where pilots have gone out and dusted an acreage only to find upon return that they wasted the material on the wrong field. What if the material was applied on a crop subject to damage? The results would be expensive as well as embarrassing. Such errors stem from carelessness and neglect on the part of the pilot to carefully check the field to be treated. There are other good reasons too for checking the field. These are described in later paragraphs. See Fig. 13 in part seven. Use of a form such as shown in Fig. 13 prevents any misidentification of the field and also serves as a constant reminder of susceptible adjoining crops or surrounding flight hazards.

Use of a form such as shown in Fig. 13 prevents any misidentification of the field and also serves as a constant reminder of susceptible adjoining crops and surrounding flight hazards.

● **FLAGING METHODS:** Few jobs can be done efficiently without a flagman. The purpose of the flagman is to give the pilot an accurate spot at which to aim in order to avoid overlaps and skips. The flagman moves over the swath width on each run. Holding a mirror on the pilot is one method of helping the pilot to quickly pick up the flagman. Usually a flagman is posted at each end of the run. Sometimes a single flagman is posted with a mirror at the center of the run. For long runs a flagman at each end and one in the center gives very efficient control. A white flag on a tall pole is most visible on a green ground.

● **TEAM FLYING:** Team flying means two airplanes using the same flagmen. This is a particularly good system to use in breaking in new pilots. It also has a number of safety features.

The experienced pilot leads. Number 2 pilot follows at a safe distance taking the next swath. While number 1 pilot is making his turn around number 2 completes his swath and makes his turn. Meanwhile number 1 is well along his swath. As soon as number 1 plane passes the flagman moves over for number 2's run. Number two pilot thus is always laying a swath right behind and can use number 1's swath for a guide. The lead pilot can keep a good watch on the work of his junior. If anything happens to either pilot the other is immediately aware of it and can render aid or report it immediately to the operating base. Usually in this team arrangement there will be three pilots for the two airplanes. This provides for one resting at all times.

● **HEIGHT AT WHICH TO FLY:** The spray discharge from an aircraft ought to be at the lowest possible safe flying height above crop. When aircraft was operated at a twenty foot altitude with a crosswind of 5 to 7 miles per hour, spray particles drifted 1350 feet, more than a quarter of a mile. At a ten foot altitude under similar conditions the drift was only 550 feet. Consult elsewhere in this booklet the drift table for various size droplets. Height of flight will affect the swath width.

●SPEED AT WHICH TO FLY: As already mentioned in this book speed of the airplane is a definite factor in the rate of application. Fly fast and the material is spread thin. Fly slowly and it is applied heavier. It is essential to apply chemicals with precision accuracy to get the desired kill and to avoid over conentration with the possibility of crop damage. This includes maintaining a uniform speed in every swath. The natural cruising speed of the airplane is generally the best speed to fly. This gives the pilot a reasonable margin of speed at which to maneuver the turn safely at the end of the swath. 45

● DIRECTION OF SWATH RELATIVE TO WIND: Generally, the best practice is to make swaths back and forth across wind working up wind. This eliminates the need for varying the air speed for up and down wind conditions. Particular field conditions such as wind breaks, other crops, livestock or houses adjoining the field necessitate varying the pattern to fit those conditions. Study the situation, weighing the advantages and disadvantages of each pattern, then select the best.

The question of flying back and forth rather than circling and flying the same direction across the field will be determined by the size of the field, obstructions and turning room. Flying cross wind offers the advantage of a uniform ground speed and rate of application.

● AIRSPEED ALLOWANCE FOR WIND: Most treatments will be made with little or no wind. Even a little wind is enough however to spoil the uniformity of coverage unless allowance is made for up and down wind differences.

Suppose, for example, that you ellect to fly with an eight m.p.h. wind. This would make a 16 m.p.h. differential between the up wind and the down wind swath. On a 70 m.p.h. constant airspeed there would be a difference in deposit of approximately 23 per cent—which would not be very uniform coverage. There is but one solution in that you cannot control the nozzle discharge. You must reduce the airspeed by an amount equal to the wind on the down wind swath and increase the air speed by the same amount on the up wind swath.

● ESTIMATING THE WIND: Blow smoke into the air—if you can keep up with it in a slow walk the wind is about 2 m.p.h. A fast walk would be about a 4 m.p.h. wind. A duster or spray airplane is calibrated and rate of application determined on the assumption of a given constant ground speed. Not only must the pilot fly at the planned ground speed but he must be aware of the wind component and correct properly for a tail or head wind.. Normally he will not be treating with very much wind but even a five mile wind results in a 10 mile differential if flying both up and down wind swaths. 10 m.p.h. on a 60 m.p.h. crusing speed means about 16 percent difference in the rate of application.

To determine direction and intensity of wind, place a smoke pot near each of the flagmen. Many operators have supplied themselves with inexpensive portable annemometers. (See Fig. 8). Using an annemometer is not only more accurate but tends to build confidence in the mind of the grower. He knows that a careful job is being done. It is also strong evidence for the job record to be able to record actual wind direction and velocity. Portable anemometers may now be purchased at nominal cost.

Fig. 8. Courtesy Associated Distributors
Portable wind direction and velocity indicator approved for required use in some states.

● ROLLING TERRAIN: Most air-applicators contend that it's best to fly rolling terrain at a constant altitude rather than attempt to follow the curvatures. Much better coverage is claimed.

● HEADINGS: Headings or bordering as it is sometimes called means flying a couple of swaths across the ends of the swaths in order to cover areas missed in the approaches and pull-ups. With this practice the planning can be so arranged that the pilot need not take unnecessary chances by trying to get in too close to power lines and wind breaks.

● DUST WHEN DEW IS STILL ON PLANTS: For many types of insecticides and herbicides it is desirable that dew is still on the plants. Dusts particularly settle and stick to the foliage when dew is still on. This means early morning application or late evening. To get the best results have everything in readiness so planes can take off as soon as it is possible to see sufficiently to fly a proper pattern over the field. This does not mean that all dusts and sprays should be applied when dew is on. There are some treatments that definitely must not be applied while dew is on the foliage.

● A THOROUGH WETTING IS NECESSARY: In order to kill weeds, a contact spray must cover the plant surfaces and wet them thoroughly. Where grasses are part of the weed growth, the spray must creep down the stems of the plants and kill the plant crowns.

Spray chemicals may be mixed with either water or oil. Oil is better spray base than water, for killing grasses, because it spreads and wets plant surfaces; water gathers into drops and rolls off. If a water spray solution is used, however, its wetting power can be increased by the addition of a wetting agent. Wetting agents may be used in concentrations of from about 0.1 per cent to 0.6 per cent or more by weight. They are also useful in mixing emulsions.66

● IMPORTANCE OF BORDER KILLS: Pests come from borders where breeding places are usually more favorable. Cleaning up a field crop is most efficient when the border areas are also treated. The advisability of using ground equipment to supplement the air equipment for getting into the corners is a matter for serious consideration if the grower is to be given a really satisfactory job.

● AVOID OVERLAPPING: Improper overlapping will result in double dosages reaching the crop plants in the overlapped area. Damage to this portion of the crop may result. Careful flaging can prevent overlapping.

● AVOID SWATH SKIPS: Swath skips must be avoided. Untreated strips between the swaths will allow weeds to mature unchecked and will produce seeds. Skilled air-applicators will use flagmen and avoid skips.

● PRESSURES: Pressures of 30 to 35 pounds are sufficient for weed spraying. At that pressure relatively good distribution is obtained with a minimum danger of drift. If danger from drift is not a consideration, higher pressures may be used, especially on weeds which may be hard to wet or where weed growth is heavy. In areas where susceptible crops are near by, the added advantages which may come from higher pressure spraying are usually much more than offset by the increased danger from drift.166

Care of Equipment

Thorough cleaning of the spray system after use and checking for leakage are two very important items of equipment care.

● CLEANING: Spray systems must be designed and proper installations be made to enable quick and easy access for cleaning. Cleaning is particularly important after the use of such highly toxic materials as 2,4-D, DDT, parathion, BHC and toxaphene. To clean systems, remove boom plugs and all screens. Use steam along with a solvent (kerosene) to cut the oils, if oil carrier has been used, and household ammonia or trisodium phosphate.

A cotton field near Baton Rouge was dusted with an insecticide that had been mixed in a machine in which 2,4-D had previously been mixed. Although the machine was cleaned as well as was thought necessary before mixing, enough 2,4-D was carried over to the insecticide to injure cotton rather severely. In this field, the yield of cotton was reduced about 60 per cent.[171]

● CLEANING 2,4-D EQUIPMENT: Spray equipment must have the 2,4-D completely removed before it is safe to apply other materials to crops sensitive to 2,4-D. The United States Department of Agriculture has recently published the following recommendations for cleaning spray equipment after using 2,4-D.

1. Flush sprayer, hoses, etc. with clear, clean water — do a thorough job.
2. Fill tank with hot water.
3. Add household ammonia at the rate of one part ammonia to one hundred parts water.
4. Close sprayer. Pump some of the solution through the system.
5. Allow closed sprayer to stand 18 hours or more. If cold water is used with ammonia, allow tank to soak two or three days.
6. Flush out through hose and nozzles.
7. Rinse with clean, clear water.

Don't store seeds and 2,4-D in the same room as 2,4-D may impair germination.[121]

● FOR OIL-SOLUBLE 2,4-D, rinse the tank first with kerosene. Follow with a rinse of lye or washing soda solution, using 1 to 2 pounds to 25 gallons of water. Leave the solution in the tank for about 5 minutes. Rinse several times with water preferably hot.[3]

● ACTIVATED CHARCOAL in suspension in the sprayer will also do a good job of cleaning and is somewhat faster than the above method. However, the filled sprayer should stand for several hours before draining and rinsing. The amount of activated charcoal needed is approximately 1% of the total volume of the tank. When 2,4-D esters have been used a thorough rinsing of the tank, pump, and booms may be made with kerosene or some light fuel oil before one of the above mentioned methods is used.

If wooden tank sprayers are to be used for 2,4-D, they should *not be used for other purposes on susceptible crops because it is almost impossible to remove all 2,4-D from the tanks.*[157]

Sprayer equipment used for general work after using for 2,4-D ought to be tried out upon such sensitive plants as tomatoes. An extra planting of tomatoes for this purpose is a good investment. If tomato plants show no effect of 2,4-D after 24 hours or more, it can be assumed that the sprayer is clean.

● DROOLING: Drooling means the leakage and drip that occurs if the system does not have a positive shut-off valve, if the installation is faulty or if there are leaks in the couplings or nozzle connections. Failure to eliminate drooling or other leaks may result in considerable damage being done to properties in adjoining fields or while ferrying to and from the field.

DO NOT EXPERIMENT

PART FOUR

ACCIDENT PREVENTION

Crop spraying and dusting is admittedly a hazardous occupation. The accident record is not good. As a result, workman's compensation in some states ranges as high as 25% of the pilot's wages.

Agricultural flying often involves take-offs and landings from short, rough fields. It involves low flying, sharp turns, abrupt pull-ups. Heavily loaded airplanes often must be maneuvered at high altitudes and under conditions of high temperatures and humidity. The agricultural pilot must have a higher degree of flying skill than that required for most other types of flying. He must be able to divide his attention between the crop, possible obstructions, his disbursing equipment and his airplane. This imposes a heavy and exacting job on the pilot and he must give *continuous attention* every second. For this reason, short rest periods are mandatory.

Members of the air-applicating industry are gravely concerned over this phase of their operations and rightly so for 165 pilots lost their lives in the 5 years from 1946-51. The frequencies of air-applicating accidents can be reduced through improvement of equipment, better maintenance, better operating methods and a safety education program. The following paragraphs suggest good safety practices and an analysis of accident causes.

Operating Rules

It is best to prepare and post where conveniently visible as a constant reminder, a set of *operating rules*. Whether you are employing a number of pilots or only one it is essential to have a clear understanding on the *rules and procedures* you want followed. A carefully worked out basic set of rules *now* will prevent many accidents and *inferior jobs*. Allow no exceptions once rules have been established. Spraying and dusting is technical and exacting. There is no place in the occupation of air-applicating for *careless* and *trifling* pilots.

● SAMPLE PILOT RULES: (1) Pilots must go over the area and inspect it on the ground before making any application. (2) Pilots must get some sleep during the middle of the day if they have had early morning flying and are to do late afternoon flying. (3) Pilots will not fly unless they have had at least a minimum of 6 hours of sleep for each of the preceeding two nights. (4) Three pilots will fly 2 airplanes, one resting while 2 are flying. (5) Pilots must not fly when they do not feel up to par. (6)Pilots will observe strictly the loading weight rules. (7) Pilots will be responsible for determining that their engine is operating normally and must not take-off if engine is not developing full power.

Flight Checking Students or New Pilots

Some pressure is being brought on the C.A.B. to require an agricultural pilots rating. Screening pilot applicants is not easy. An agricultural rating would help some in eliminating the inexperienced pilot applicant. Careful selection and screening would still be needed however. Following is an incomplete list of maneuvers useful in checking out new pilots:

1. Slow flight — straight and level.
2. High speed stalls — pull-ups and turns.
3. Low airspeed turns — have pilot demonstrate both coordinated and cross control.
4. Fast recovery from turns.
5. Near stall take-offs.
6. Power and power-off landings.
7. Pilots ability to fly level when horizons are misleading, such as low flying between ridges of terrain.
8. Appreciation for various gross loadings, temperature, humidity and elevation conditions.

Suggestions for Pilot Training

1. Flight check in the type airplane used in actual operations.
2. Don't overload plane when breaking in new pilots — until pilot is ready.
3. A good sound flight check on the maneuvers necessary to dusting and spraying operations will either discourage a weak applicant or indicate a well trained, competent, agricultural pilot.
4. Train pilots to never relax attention (90% of the agricultural accidents are due to collisions with trucks, fences, rock piles and buildings on the ground or wires, trees or other airplanes in the air. Stall accidents are indirectly collision accidents for the pilot stalls the airplane attempting to avoid the wires or tree tops.
5. Train pilots to keep their hand on the throttle — not the spray valve or hopper handle.

● **DISCUSS HAZARDS WITH PILOTS: An excellent practice is to have the ground crew (flagman particularly) discuss field hazards with the pilot. Often pilots may finish a job and transfer over to assist in another job already underway. He may not take as much time under these circumstances as he normally would to make a ground check. It is therefore the responsibility of the person managing the job to have the hazards discussed with the pilot. It will help him to be cognizant of the hazards.**

ANALYSIS OF 1948 ACCIDENTS

In 1948 the fatalities per accident among crop dusters were about 20% above other types of non-scheduled flying. The destroyed aircraft was 40% higher per accident. There must be a reason. It certainly must not be a lack of pilot experience or skill for the pilots involved in the crop dusting accidents over 81% had at least 1000 hours of flying. It must be the nature of the work; the necessity of low flying, quick pull-ups, and tight turns. These practices have resulted in the following statistics for crop duster accidents:

49% — Collisions with trees, wire, poles, standpipes, etc.

27% — Landing gear failure, fires, engine failure, take-offs and landings, etc.

24% — Stall-spin accidents

The last 24% are caused by stalls at low altitudes followed by a tendency to spin. It is probable that some of the 49% are also the result of a stall in a quick pull-up to avoid obstacles, making further climb impossible and a collision inevitable. While the stall-spin type only represents a minority of the accidents, it is responsible for the greatest number of fatalities, (37%) and is therefore the greatest potential hazard to the crop-duster.[308]

ACCIDENT CAUSES

Overloading

Overloading has been a contributing cause of many agricultural accidents. Airplanes are certificated for a gross loading which allows a reasonable margin of power for emergency use. Even when loads are kept within the gross limits there are many variables that often are cumulative in their adverse affect on performance. See Fig. 11 later discussion of rate of climb relation to various gross weights.

High humidity and high temperature together with a down draft, a slight skid in slow flight while loaded heavily may put the airplane into an obstruction in spite of anything the pilot can do. Some applicators have used a loading scale based on the air temperature. Others have set arbitrary load percentages for various hours of the day. These devices are good but do not relieve the pilot of the necessity for good judgment and constant alertness to the airplane performance.

Heavy loading requires greater pilot skill even under ideal flying conditions. Turns, pull-ups, climbing turns, all become more critical with increased gross weight. These factors become still more critical when flying at high terrain elevations and when the temperature and humidity are high.

"A pilot flying a Piper JC 3 at Amery, Wisconsin, on June 8, 1949, was making a simulated dusting run at low altitude carrying a full load of and 175 pounds of dust. He gained very little altitude at end of run before attempting a 180 degree turn. Aircraft stalled and crashed before recovery could be effected."

Line Checks

Line checking has always paid off in preventing accidents. Fabric tears, tire wear, bent longerons, loose screws, worn fittings and cables, these and many other defects have been discovered by a simple line check prior to flight. The best pilots always do this even when it is the known duty of a lineman or ground crew to do it. Agricultural airplanes are always subject to the meddling or collision damage of workmen on the job not familiar with planes.

Sulfur Fires

Many instances are known of duster pilots seeing fire in the dust behind them, and shutting off the dust supply, starving and extinguishing the blaze. Occasionally a flash of fire envelopes the whole area dusted without doing damage.

When sulfur dust is in the air in the proper proportion it will ignite easily. In calm air, as in the conditions under which this accident happened, dust hangs and if there are thermal currents, it may rise instead of settling to the ground. The exhaust stack of the engine must, therefore, be placed above the plane to avoid igniting the dust. However, this placement of the stack cannot prevent fire if a previously laid cloud of dust is flown through.

"Pilot Hardin of Edinburg, Texas, took off with 500 pounds of sulfur to dust a citrus grove approximately 10 miles away. Weather was clear and calm, with a slight east breeze later. Witnesses watched the

pilot make two dusting trips over the grove in a north-south direction, starting from the west side of the grove and working east. When about midway across the grove on the third trip, flying south, fire was seen stretching out behind the plane, fed by dust from the hopper. The pilot was seen to lean over the side of the cockpit. At the same time the flow of dust was shut off, stopping the fire. After this initial fire, the aircraft was climbed as though to head for the airport, but when it reached 200 feet a cloud of sulfur was seen to come from the hopper and the dust started blazing again. The pilot then made a 45° turn to the left toward an open field as though intending to make a landing. Dust continued to flow out of the hopper to feed the fire, and fabric on the fuselage began to burn. The aircraft continued toward the field losing altitude with the engine running until it struck the ground in a citrus grove next to the field. The aircraft went over on its back and was completely destroyed by impact and fire."

DEPARTMENT OF COMMERCE

January 19, 1942

SAFETY REGULATION RELEASE NO. 89

SUBJECT: Causes and Prevention of Fire Occurring While Engaged in Spreading Sulphur Dust with Aircraft.

PREPARED BY: Aircraft Engineering Division

In April, 1940, the Civil Aeronautics Administration issued Airworthiness Maintenance Bulletin No. 24 recommending that certain alterations of a fire preventative nature be made to all aircraft engaged in spreading sulphur dust. Since that time, however, two additional reports of the occurrence of fire during sulphur dusting have been received, indicating either that the recommendations of Airworthiness Maintenance Bulletin No. 24 have not been followed or that the recommendations themselves did not cover all contingencies.

The purpose of this release is to review the problems involved and to present to persons engaged in sulphur dusting with aircraft such information as is available on the prevention of fires during such operations.

The material contained in this release is based on information received from the following sources.

1. Owners and pilots actually engaged in sulphur dusting operations. (Replies to questionnaire circulated with Airworthiness Maintenance Bulletin No. 24)

2. Fire protection and prevention associations.

3. Accident reports received by the Civil Aeronautics Administration.

As is generally known, sulphur has a very low ignition point and is highly combustible when atomized with air, which is the case during dusting operations. Also, due to its excellent dielectric properties, it picks up electric charges readily, which, under favorable atmospheric conditions of low relative humidity, can lead to combustion. There are cases on record of sulphur igniting when thrown from a workman's shovel during handling operations. Although such occurrences are rare and must necessarily occur under the most favorable of circumstances, they serve as examples of how easily sulphur can be ignited.

During industrial handling of sulphur (pulverizing, grinding, etc.) every effort is made to prevent the formation of a cloud of sulphur dust because

Fig. 8.

"Pilot Webb of Louisville, Kentucky, took off on his second dusting trip of the day. He had loaded with 350 pounds of sulfur. To dust the citrus trees in this triangle it was necessary to climb over the shade trees and dip down abruptly to a height at which the dust would be effective. As pilot Webb attempted to dust these trees, and with the hopper open to permit the dust to flow out, he severed the power line. Immediately the sulfur dust ignited. The aircraft continued southeast with the wire clinging to it for approximately 200 feet, then flew for another 1000 feet, and crashed in an open field. It went over on its back and burned."

Collision with Trucks

Many accidents have occured while taxiing up to servicing trucks. Much better is to have the loading facilities such that the truck can *move up* to the parked plane. "While dusting a field a pilot flying a Stearman N3N at Coolidge, Arizona, on July 23, 1947, failed to observe a tractor and driver and struck them, seriously injuring the trac-

tor driver. One side of landing gear was damaged and pilot landed at his base on one wheel and ground looped."

Flag All Rock Piles

Rock piles have been struck many times. To assist the pilot in avoiding them they should always be marked with flags on tall light poles.

Steep Turns

Steep turns, particularly *steep climbing turns,* are a common cause of agricultural accidents as in other types of flying. Pilots should occasionally review their stall speed vs degree of bank formula. The practice of increasing power on all turns is a necessary one. Steep turns down wind involve *inertia effect* which adds to loss of lift. Agricultural pilots should be very familiar with this theory.

"Pilot Wimp of Hollywood, Florida, proceeded to a small tomato field where he was engaged in dusting operations. A witness observed the plane make several swaths back and forth over the field. Following the last swath the pilot pulled the airplane up abruptly into a steep left turn to clear a row of palm trees and the grandstand of the Gulf Stream Park Race Track which adjoined the field being dusted. When approximately 180° of this turn had been completed the plane was stalled. The left wing dropped and the plane, after about one-half turn of a left spin, struck the ground nose-first in an almost vertical attitude approximately 50 feet from the grandstand."

"Pilot James of Willows, California, made a sharp climbing turn, and leveled off at a very low altitude. After completing another seeding run he started another steep climbing turn to the left. The airplane apparently was stalled at the top of the turn and before recovery could be effected it fell off to the right, crashed on its right wing and nose, bounced forward around 200 feet and came to rest upright."

"Pilot Sanders of Homestead, Florida, took off solo with a 600-pound load of insecticide to dust nearby pepper crops. Soon after leaving the ground he started a steep turn to the right. When this turn had progressed nearly 180° the right wing tip struck the ground. The plane then cartwheeled and came to rest about 150 feet beyond. It appears that a steep turn was necessary in order to avoid the trees."

Fire and Explosion Hazards

Many insecticide solvents such as kerosene are inflamable especially in the forms of sprays and mists. Avoid having them near an open flame or lighted cigarette.

Check All Planes In

A crew chief or someone ought always to remain on the job until the pilot returns and lands safely following his last load. On several occasions there have been landing accidents on the final landing. In one case a pilot hung on his safety belt all night because there was no one to assist him when he nosed over in a soft spot.

Steep Climbing Turns

"On July 22, 1946, at Stanwood, Washington, while flying a Piper J-3 was dusting in such a way as to require tight climbing turns due to the terrain, and a heavy load of dust was being carried. In turning at the end of a run the ship stalled and spun in. Explosion and fire followed. No evidence supporting any mechanical trouble theory."

Stalls

All stall accidents can be said to be the result of the pilot failing to maintain sufficient flying speed for the type of maneuver. Other *contributing elements*, however, enter into stalls.

Airplanes stall out at higher speeds in pull-ups, sharp turns and climbing turns, particularly when heavily loaded, flying at high altitudes and with high temperature and humidity conditions. These factors are critical in agricultural flying because the sprayer or duster is usually flown at speeds slower than their normal cruising speed. See Fig. 10 for chart showing the rate of climb correction necessary for various temperatures.

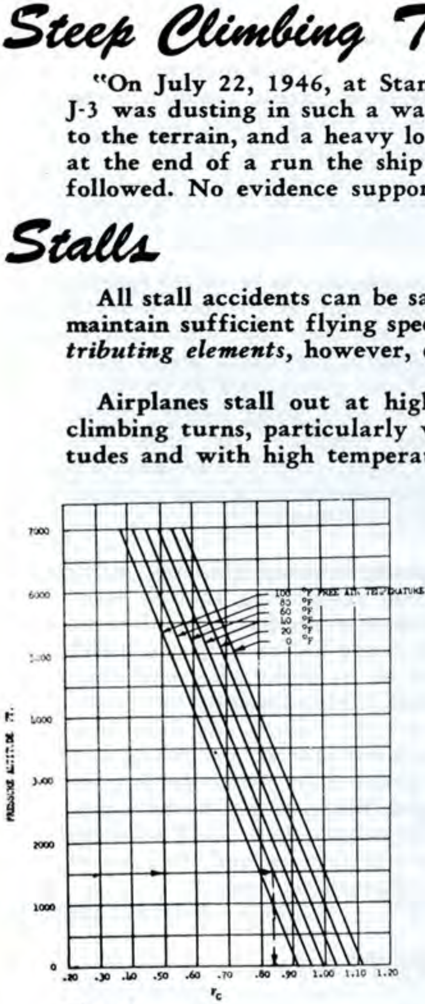


Fig. 10.
Rate of climb correction for altitude and temperature.

Stall warning devices are highly recommended by the FAA and are being experimented with by some air-applicators. As yet there is insufficient experience to indicate the value of the stall warning device in agricultural flying. Stall resistant airplanes are also being experimented with. The FAA prototype agricultural airplane described in Volume IV is stall resistant. Stall resistance is obtained at the cost of reduced maneuverability to some extent.

A typical straight and level flight stall accident is illustrated by the pilot who flew low and slow in order to observe flags which were to indicate if he should return to his base. While flying low he let his air-speed drop off too much and crashed.

Looking for a place to land, a pilot flying a Piper JC-3 at Adel, Georgia, on June 18, 1950, "stalled out" by trying to stretch his glide into a corn field. Evidence indicates engine cut out or malfunctioned and pilot was attempting to land in a corn field, when aircraft stalled at an altitude too low to effect recovery.

Turbulence

Airplanes damaged through gusty air conditions have usually occurred while ferrying or testing rather than while dusting or spraying, inasmuch as little application is done in wind conditions.

"Pilot Montgomery of Tallulah, Louisiana, took off from Tallulah with a load of insecticide and flew to a plantation between Waverly and Epps, Louisiana. Here he dusted crops until about 10:45 a.m. then landed on an adjacent strip to reload. At this time he remarked that it was getting rough and windy and that he was going to finish as soon as possible. He took off and flew at an altitude of about 50 feet. The wind was south 25 m.p.h. and gusty. At the end of a southbound run a steep turn was started to the right. This turn had progressed nearly through 180° when the aircraft fell off to the right and crashed. The probable cause of this accident was failure to maintain control of the aircraft during a steeply banked down wind turn near the ground. A contributing factor was the strong gusty wind."

Abrupt Pull-ups

Abrupt pull-ups often result in the high speed stall. Agricultural pilots should review the facts on high speed stalls in order to keep themselves reminded that sharp pull-ups often result in excessively high angles of attack for current air speeds and induced stalls.

Exhibitionism

There are exhibitionists even in agricultural flying. These pilots, aerial acrobats at heart, can't resist the urge to slow-roll, snap-roll and loop. These accidents usually occur while returning to their bases.

After his plane was loaded with 300 pounds of dust a pilot flying a Boeing N1 at Monroe, Louisiana, on July 7, 1946, took off but returned back over the field descending to 200 feet where a maneuver which was apparently an intentional *slow roll* was made. On recovering from this the airplane veered off to the right toward some trees. The pilot tried to go under some high branches but the plane struck some power line wires about 50 feet from the trees, crashed and burned.

"A pilot flying a Piper JC 3 at Willows, California, on May 25, 1946, apparently attempted a wingover at an altitude of 200 feet during a landing approach. The plane was stalled and it crashed before recovery was possible. Fire developed upon impact and the aircraft was destroyed."

Collisions

A number of collisions between agricultural airplanes or other airplanes have occurred at airports and in the vicinity of their agricultural operations. Collision avoidance is a matter of continuous visual alertness on the part of both pilots, the observance of which there is no substitute.

"Pilot Whitaker of McGehee, Arkansas, was dusting a 290-acre cotton field east of a highway which runs north and south. and Pilot Harvey was dusting a 75-acre cotton field on the west side of the same highway. This allowed a separation of from ¼ to ½ mile between the two flights. About 7:45 a.m. Pilot Harvey of Corsicana, Texas, was headed south, dusting parallel to the highway and had just pulled up to an altitude of 50 to 75 feet to clear farm buildings when the Stearman flown by Pilot Whitaker approached, headed west, across the south end of the field Harvey was dusting. Harvey apparently saw the other aircraft and attempted to avoid it by an abrupt right turn. The propeller of the Stearman cut the tail off the Keystone and both planes crashed and were destroyed by resultant fire. No reason could be found why Whitaker should leave his work and fly across the field being dusted by Harvey. Both pilots had been given specific instructions that they were not to cross each other's flight path."

Most of the collision accidents are those with *surface objects*, such as servicing trucks, bait mixers, fences, piles of rocks, trees, shovels sticking in the ground, etc. "Pilot Wills of Pine Bluff, Arkansas, dusted oat fields for approximately seven hours. At about 6:30 p.m. he was flying a north bound run with a tail wind. At the northern end of this run was a marking flag. Willis approached this flag at an altitude of about 25 feet and then attempted with full throttle to zoom over a 75-foot tree about 100 feet beyond the flag. The left wing struck some o the top branches of the tree and the aircraft, after continuing ahead for a short distance, plunged to the ground and struck on the right wing and nose."

Collisions with telephone wires and power lines also account for a large share of the collision accidents. "Pilot Long of Santa Maria, California, resumed dusting a field of celery near Guadalupe which he had partially dusted two days before. During the pull-up at the end of his first swath, the tail wheel struck and severed three wires of a power line and one of the wires became entangled around the tail wheel. The plane continued upward about 50 feet then stalled and

spun to the ground. It is possible that the pilot's vision may have been restricted somewhat by an accumulation of dust on the goggle lenses, which is possible in this type of operation."

"A pilot flying a Travelaire 4000 at Stockton, California, on August 3, 1946, was dusting a tomato field and flew under a power line which bordered the field. He missed the power line but flew into a phone line on the opposite side of the road. The aircraft crashed and burned in the next field."

"A pilot flying a Stearman N3N at Grace, Mississippi, on March 10, 1948, had just taken off with a load of seed when he experienced some engine difficulty and decided to return to the airstrip and land. In the meantime a truck had been driven down the strip to about the center point where the truck driver was apparently going to turn around. The pilot failed to observe this truck, landed and had rolled about 500 feet when the truck was struck. The truck was turned over and its cab demolished, seriously injuring the driver, who died five days later."

"A pilot flying a Curtis Robin near Dutton, Mantana on May 28, 1950, was completing his last spraying run and the right gear was sheared off as it struck an automobile traveling along on an adjoining country road. The left portion of top and windshield of car were ripped open. Car ran off road into a gully. A three year old child riding in front seat received fatal injuries. Two adults in front seat received serious cuts. Pilot did not observe car at anytime. Aircraft was flown back to airport base and landed safely."

Flying Uphill

Flying *uphill* without recognizing it or being cognizant of a progressively increasing angle of attack has been one of the most serious causes of fatal accidents in the forest spraying of the northwest. Many of these fatal accidents occurred to pilots of limited or no experiene in mountain flying — flying in which the plane is flown into draws and canyons where the pilot loses the true horizon. When flying below the ridges the ridges are sometimes inadvertently used by the pilot as a horizon. Obviously, ridges can be badly misleading.

"Pilot flying a Boeing 247-D at Walla Walla on June 27, 1950 was engaged in spraying forested area in mountainous terrain in Spruce bud worms control. Aircraft was flying up a steep draw when it collided with trees, crashed and burned."

Pilots experienced in mountain flying follow the practice of coming in for the spray run high and always making the turn down hill for the actual spray run. This, of course, means a one way operation but it is a safe operation. Flying up a canyon or side hill and having to make a climbing turn to get out many times requires a rate of climb greater than the plane can deliver.

● **PLANE STRUCK FLAGMAN:** On May 22, 1950, a pilot flying a Stearman N3N at Kahlotus, Washington, when nearing end of dusting run, made at an altitude approximately six feet the right tire struck the flagman causing fatal head injuries. Evidence indicates the flagman had been facing the approaching aircraft, and for some unaccountable reason failed to change his position or attempt to get out of the way of it.

● **PILOT WAS BLINDED BY DUST:** At Palmyra, Pennsylvania, on August 3, 1946, a pilot's goggles steamed up while dusting and he removed them. Was then blinded by dust. He tried to land but stalled and crashed.

● **PILOT TURNED ON WRONG FUEL VALVE:** During conversion of a Travelaire 4000 at Medford, Oregon, in 1946, 3 fuel valves were left in, 2 of which were dummies. Pilot inadvertently turned on one of the dummies and took off without warming the engine. During the climb the engine starved and pilot endeavored to turn back. The plane stalled and crashed.

● **FAILURE OF A WELD:** Evidence indicates conclusively, that a Boeing N1 at Homestead, Florida, failed in its welded control link at an altitude of about 200-400 feet while the plane was in normal flight and it dived to the ground.

● **SPECTATOR WALKS INTO PROPELLER:** A pilot flying a Boeing N1 at Gould, Arkansas, on March 3, 1950 landed to reload hopper with seeds. He allowed engine to operate at idling speed while he deplaned in order to check the hopper door, before taking off, as it appeared to be stuck. Several spectators nearby were cautioned by pilot to remain clear of the aircraft. However, one fifteen year old boy disregarded this warning and walked into the propeller. Pilot failed to exercise due caution in allowing engine to idle or in not placing a guard to keep onlookers away.

● **CHILDREN THROW TOMATOES AT PILOT:** At Peru, Indiana, some children, told to leave a tomato patch being dusted, threw tomatoes at pilot as he was making a run. A tomato hitting him in the face stunned pilot momentarily and aircraft was flown into the ground. Following first impact aircraft ballooned then dropped back in and caught fire.

● **TAKE-OFF IN HIGH GRASS:** A pilot flying a Boeing A75N1 at Petronila, Texas, on June 5, 1950, landed on an abandoned strip to repair a leak in hopper. Then as he attempted to take off tall weeds prevented aircraft from gaining flying speed and although he opened hopper the dust did not dump fast enough to lighten load. Brakes were applied in an effort to ground-loop away from a fence, gear bogged down and aircraft nosed over. Pilot was burned as sulfur which had ignited covered his face and head. Sulfur apparently burned itself out and did not spread to aircraft.

● POOR PHYSICAL CONDITION: Poor physical condition causes some accidents as indicated in this report. Pilot of Rice Lake, Wisconsin, flying an Aeronca 7 AC was returning to airport after completing spraying operations when he lost control of aircraft and crashed in a wooded area. Later investigation revealed pilot, unknown to his partners, was subject to fainting spells and was undoubtedly an epileptic.

● FUEL EXHAUSTION: Pilot flying a BT 13 at La Grande, Oregon, July 3, 1950 — Evidence indicates engine failed due to fuel exhaustion. Aircraft apparently stalled and dived into the ground. Pilot was spraying forest area in mountains for spruce budworm.

Helicopter Accidents

Helicopter accidents have consisted mostly of ground crewmen and others walking into the rotors. This is one of 7 helicopter accidents in which crewmen or bystanders walked into the tail rotor. June 27, 1950, at Yakima, Washington, a ground crewman walking around a helicopter which was being warmed up on the warm up apron, slipped on some loose gravel and his arm was struck by the tail rotor.

Relation of Weights to Performance

Fig. 11 shows the approximate maximum rate of climb available at various weights for several typical models used in agricultural operations. It is significant to note that the FAA in analyzing the airplanes used in preparing the chart shown in Fig. 11 found that the converted airplanes experienced climb reductions in the order of 15 to 30%.

It is important to further note that at weight increases of 20% above the basic weight used in preparing the chart, climb *reductions* of 45 to 75% were obtained.

● FOR EXAMPLE: Referring to Fig. 11, an Aeronca 7 AC that had a rate of climb of 285 feet per minute with a loading of 1350 pounds, had only a 100 feet per minute rate of climb when loaded to 1650 pounds.

Weight is the most important of all factors affecting climb performance, while such other factors as drag, temperature, humidity and altitude are relatively fixed items, the weight of the plane can be controlled. Weight adjustments to stay within safety margins, can be made in either the fuel or chemical load carried.

Influence of Altitude and Temperature on Climb

The influence of altitude and temperature on climb performance was determined from an analysis of data which was available for a number of non-agricultural category aircraft. A chart showing rate-of-climb correction for altitude and temperature, Fig. 11, was prepared from the results and assumed to apply to aircraft equipped with sprayer and duster equipment. A study of this chart indicates that climb increases approximately 2% over the climb at standard temperature, 59°F, for every 10°F decrease in air temperature. Conversely, climb performance decreases approximately 2% for every 10°F increase in air temperature. The effect of altitude indicates that there is a reduction in climb of approximately 8% for every 1000 feet.

Model	Engine	CAA Approved Maximum Weight Lbs.	Best R/C Speed MPH TIAS	Weight Lbs. vs Rate of Climb Ft./Min.						
				Wt. / R/C	Wt. / R/C	Wt. / R/C	Wt. / R/C	Wt. / R/C	Wt. / R/C	Wt. / R/C
Aeronca 7AC	Continental A65	1340	54	1350 / 285	1400 / 250	1450 / 220	1500 / 190	1550 / 160	1600 / 130	1650 / 100
Aeronca 15AC	Continental C145	1750	70	1750 / 610	1850 / 575	1950 / 515	2050 / 455	2150 / 400	2250 / 350	2350 / 300
Boeing 75	Continental W670	3520	68	3500 / 270	3550 / 250	3600 / 230	3650 / 205	3700 / 185	3750 / 165	3800 / 145
Boeing 75	Lycoming R680	3520	70	3500 / 530	3600 / 480	3700 / 435	3800 / 390	3900 / 345	4000 / 300	4100 / 260
Boeing 75	Pratt & Whitney R985	3520	71	3500 / 1180	3600 / 1120	3700 / 1050	3800 / 990	3900 / 930	4000 / 870	4100 / 820
Navy N3N-3	Pratt & Whitney R985	3740	72	3800 / 1030	3900 / 960	4000 / 900	4100 / 840	4200 / 780	4300 / 730	4400 / 680
Piper PA-11 & J3C-65	Continental A65	1250	54	1250 / 410	1300 / 375	1350 / 335	1400 / 300	1450 / 270	1500 / 240	1550 / 205
Piper PA-12	Lycoming 0235-C	1735	63	1750 / 340	1800 / 310	1850 / 280	1900 / 255	1950 / 230	2000 / 205	2050 / 180

Fig. 11.
Rate of climb for various gross weights for several agricultural planes.

The following example is given for the purpose of demonstrating how to approximate the maximum rate-of-climb available for an airplane which is being used as a crop duster.

● EXAMPLE: Crop duster operations are to be conducted in a Navy N2N-3 airplane which has been loaded to a gross weight of 4050 pounds. What will be the approximate maximum available rate-of-climb if the air temperature is 80°F and the airplane's altimeter registers a pressure altitude of 1500 feet?

Solution — From Fig. 11, the approximate maximum available rate-of-climb for the Navy N3N-3 at a weight of 4050 pounds is 870 feet per minute. From Fig. 10, the correction factor Fc, is determined to be

.84 for a temperature of 80°F, and a pressure altitude of 1500 feet. The maximum rate-of-climb for the above conditions is calculated to be:

870 x .84 equals 730 feet per minute

SUMMARY OF 1947, 48 and 49 ACCIDENTS

(Taken from C.A.B. report)

Of the 250 agricultural flying accidents reported in 1947, 48 and 49, 81% were due to only 4 general causes. They were stalls 34%, striking wires 25%, striking trees 13%, collision with other objects 9%.

Actually striking wires and trees is also a *collision* type of accident and as such collisions characterize 47% of the accidents. A study of the *stall* accidents reveals that stalls eminate from two causes. One, excessive angles of attack, particularly with heavy loaded planes and bad air conditions, but not while attempting to clear obstructions. The second, involves pull-up to avoid hitting wires and trees. The latter cause characterizes the majority of stall cases. Many pilots avoided collisions with wires and trees only to immediately stall and crash. This gives added significance to *collisions* as the most general characterization of agricultural flying accidents. Training agricultural pilots then involves training in avoiding collisions not only with other airplanes on the ground, persons, trucks, and buildings, but also with wires and trees.

Although few in proportion, the remainder of the causes of agricultural flying accidents are important and should be studied by all agricultural pilots. Of the 250 reported accidents, eight were due to exhibitionizm, seven to engine failure, eight to bad terrain for take-offs. Seven persons walked into rotating tail rotor of helicopters. Looks like C.A.B. would require a simple safety ring around the tail rotors.

Of the balance of the 250 accidents, one airplane ran away while being cranked without anyone at the controls, 2 caught fire in the air, 2 pilots were blinded by dust, there were 5 mechanical failures, 3 appeared to be caused by impaired pilot health, 2 persons walked into propellers, 2 pilots ran out of fuel and 3 flagmen were killed by pilots striking them with their wheels.

Often in FAA —C.A.B. statistical reports on accident causes, 75% of the accidents are charged to pilot error as the cause. ***This generality means nothing***. The following paragraphs list specific causes of accidents **and resumes of actual cases.**

● STALL SPEED of an airplane varies with weight, C. G., loading, type of maneuver (tight turn, quick pull-up), power, etc.

Facts About the Stall

● **STALL SPEED** usually quoted for an airplane is that with power off, gross load, straight unaccelerated flight with the speed slowly reduced by back pressure on the stick. The speed at which the best angle of climb is obtained is usually about 25% *above stall speed.* If the airplane is flying at lower speeds its ability to climb is reduced until at the stall it is zero.

● **TIGHT TURNS AND RAPID PULL-UPS** increase the stall speed. (A 2 "G" pull-up or a 60° banked turn without altitude change will increase the stall speed 40%.)

● **OVERLOADING** increases the stall speed. (25% overload increases the stall speed 12%).

● **A C.G. LOADING BEYOND THE ALLOWED LIMITS** will increase the stall speed, all depending on the degree of loading beyond the C.G.

● **WITH FULL POWER** the stall speed of an aircraft will generally be about 10% lower than that with no power.

Of lesser importance is a *change in the sprayer boom or the spreader* which may disturb the flow of air over the wings or tail resulting in a higher stalling speed.

Loading is important not only in stalls, but also in handling characteristics. As the C. G. is moved aft the airplane becomes more unstable, the stick forces are reduced, the controls become sluggish and increased attention is necessary to keep it on an even keel. As the C. G. is moved forward the control forces may exceed the values desirable for an airccraft that is being constantly maneuvered. With proper loading, the stable airplane will fly with less pilot effort, giving more time for safe flight planning and more alertness for potential hazards.

To aid in preventing stalls the following practices are recommended:

1. *Keep the airplane loaded within the C. G. limits.*
2. *Keep the loading down to a reasonable amount.*
3. *When in the vicinity of a stall use full power.*
4. *Keep the speed well above the stall.*
5. *Avoid sudden pull-ups and tight turns.*
6. *After any new installation check the stall characteristics.*

Write to the Civil Aeronautics Board, Accident Analysis Division, Commerce Building, Washington D.C., for brief resumes of agricultural accidents similar to those cited.

AIRPLANE SAFETY ITEMS

Protection from Toxic Materials	Shoulder Harness
Fire Extinguishing Equipment	Crash Protection
Location of Instruments	Airplane Design
Ventilation of Cockpits	Safety Belts
Adjustable Seats	Visibility

These are some of the safety items in agricultural airplane design. There is now available an excellent FAA manual which discusses in full detail each of these. FAA Manual 8, not only treats these subjects but also provides a wealth of additional material valuable to all air-applicators. See elsewhere for further description.

PART FIVE

SELECTING CHEMICALS

The choice of chemical type of formulation, time and method of application requires a broad knowledge on the part of the one responsible. The following paragraphs present a number of the factors which must be kept in mind when making decisions. Part V also lists many reminders relative to the handling of dangerous chemicals.

The things that ought to be considered when selecting an insecticide are:

(a) effectiveness of material

(b) plant injury characteristics

(c) drift control

(d) residue control

(e) dosage

(f) cost

There is usually a particular insecticide that will give best results. For example, for control of the corn earworm on tomatoes DDT or DDD gives best results and *not* nicotine, rotenone, pryethrum or Tepp. For the control of aphids on melons use nicotine or parathion *not* DDT, calcium arsenate, toxaphene or cryolite. 50

Make sure that the material used will not injure the crop being treated. Check with your local state college of agriculture authorities.

Some plants are easily injured when moist with dew or rain. For example, dinitros should not be used on peas or flax when they are wet with dew or rain. Some plants are easily injured by some chemicals when the temperature is high, for example, lime sulfur at temperatures above 90°. If treatment must be in the vicinity of other susceptible crops, select a spray least likely to damage. For example, use DDT instead of calcium arsenate dust for the control of caterpillers attacking tomatoes or use DDT to control leaf hoppers or beetles on melons.

To avoid a residue problem use such insecticides as nicotine pryethrum, rotenone, or tepp. These chemicals because of their volatility can be applied almost up to harvest time without danger of excessive residue. Other insecticides should be used only in the pre-blossom stage or early enough to allow for residue deterioration before harvest time.

Types of Insecticides

Insecticides are of three general types. When applying a material keep in mind how it does its work. The selection of chemical is based upon the method with which the chemical killing takes place in the insect. (See Volume One "Agricultural Chemicals" for a complete discussion of the types of insecticides.)

● **CONTACT** insecticides are those which are effective with insects that have piercing bills and suck the juices from leaves and stems of plants, such as aphids. The insecticides get into their system by the physical contact of the insect with the poison rather than through their stomachs.

● **STOMACH** insecticides are those that are used primarily in combating insects which chew foliage such as beetles and caterpillers.

● **FUMIGANTS** are insecticides that are breathed by the insects and affect the respiratory system. Hydrocyanic gas is an example of this type insecticide and is adaptable to granaries and other buildings.

Contact poisons are more general in that often they are effective as both contact and stomach poison, whereas, stomach poisons are limited to insects with chewing mouth parts.

Importance of Species

Most insecticides, fungicides, and herbicides are very specific in their action against different species. A given insecticide may be highly effective against one insect and absolutely worthless against another species. The same applies to fungicides and herbicides. For example, DDT will give excellent control of certain species of aphis, while it is absolutely worthless as an insecticide when used against another aphid species. The action of 2,4-D is an outstanding example of specificity among the herbicides. Always be certain that the material to be used will kill a maximum number of the insects you are after, and a minimum of other, beneficial insects.

Advantages of Spray over Dust

Liquids when applied with proper spreaders or stickers adhere to plant surfaces better than dusts unless *dew* is present. Dusts as a rule must be applied from very low altitudes as compared to sprays. Liquids are less likely to be washed off plant surfaces by rain than are dusts. Generally speaking, it takes appreciably more of the pure chemical to do the same job with dust than it does with spray. Often one spray application will give better results than two or three dust applications. Sprays can be carried on safely at wind velocities in which dusting would be very ineffective as well as highly hazardous.

Dusting materials may control orchard pests if thoroughly applied at the proper time. Generally speaking, you can expect good control from these materials. You must apply the *same amount* of the active ingredient of the insecticide per acre or per tree as you have been applying in spray form. It is also necessary that the applications be made when atmospheric conditions permit most of the dust to settle in the trees. Be careful *not* to dust when air drift may carry the material to other crops. Dusts have often been much less effective against well-protected insects, such as the wooly apple aphid, than against orchard mites and other more exposed pests. Their effects are not as long lasting as sprays, necessitating more frequent applications.58

CAUTIONS IN CERTAIN APPLICATIONS

Selecting and using chemicals in pest control is highly technical. Much of the information needed on the effectiveness and safety of chemicals on specific plants and species is available only from experts. Consult with them *often* and *fully*.

Air-applicators should proceed slowly in the matter of analyzing and recommending. The advice of local and state pest control authorities ought always to be sought first. Never should the use of chemicals on plants be *taken for granted*.

In the following paragraphs are a few common warnings and precautions. This list is a partial one only. The Air-Applicator Institute has made no attempt to list all of the precautions.

Decomposition of Materials

Some dusts and sprays decompose very rapidly. They should be gotten to the insect as soon as possible with as little exposure to the elements as possible. This is particularly true with such insecticides as pyrethrum, rotenone and other of the natural materials.

Dust formulations of tepp show various degrees of stability, therefore only the most stable ones should be used. Loss in application must always be considered. Chlordane, for example, is rather volatile. More of it is lost when applying a fine mist than when applying a coarse spray.

Plant Growth Regions

When applying penetrating oils study the physiology of the plant to learn where the *growing region* is located. When killing weeds the penetration should reach the *growing region*. When killing insects you need to avoid getting toxic materials on the *growing region*.

In applying a *selective* spray you may exceed the margin of selectivity by: (a) using too much chemical (b) too high a spray pressure (c) wrong timing (d) too high temperature (e) too much humidity (f) wrong form of chemical (g) improper method of application.

A general *contact* spray must be applied so that it gets maximum spread over all the surfaces of the plant. Toxicity of herbicides and insecticides is always *limited* by the tolerance of the crop on which it is applied.

GENERAL PRECAUTIONS:

★ Always read all of the directions on the labels of the containers.

★ Follow recommendations carefully.

★ *Never* overdose.

★ Never use more solution to the acre than is recommended.

★ Use a good source of water.

★ Check for drooling or other leaks before each job.

★ Screen all materials before putting them into spray tanks.

★ Study the label on the container.

Here are a few of the good reasons for following the *label directions* on the chemical containers:

1. Chemicals lose their effective characteristics when not used precisely as intended and may even be very damaging.

2. Chemicals change their characteristics when any element is omitted or undesirable element added.

3. Temperature and humidity may alter to the point of unusableness many chemical preparations.

4. Freezing may alter some preparations to where they are not only useless but harmful to plants.

5. Many materials are incompatible.

6. Some chemical materials neutralize and make ineffective others.

1947 Cotton Injury in Louisiana

In Ouachita and Morehouse parishes some 10,500 pounds of 15 per cent dusts were applied by plane. (Use of 2,4-D dusts now prohibited by FAA). Injury was found on 1748 acres of cotton, classified as follows: dead and dying, 297 acres; heavy, 471 acres; moderate, 404 acres, light, 256 acres; trace, 320 acres; and no injury on an additional 1,806 acres surveyed. A survey in the Pine Prairie area of Evangeline Parish showed injury on 86 farms and the degree of injury was classified as follows. heavy, 192 acres; moderate, 62 acres; light, 74 acres; and trace, 117 acres.171

REMINDERS

● ANNUALS are most susceptible while young — perennials are most susceptible just before bloom.165

● BORAX is a slow acting, long lasting chemical causing soil sterility. It should not be used where sterility is objectionable.

● BENZENE HEXACHLORIDE: Growers are cautioned about the use of benzene hexachloride late in the development of fruits and vegetables. Reports have come from various areas that fruits and vegetables have been unmarketable because of the musty benzene hexachloride flavor. Do not apply BHC later than eight weeks before harvest. BHC causes injury to cucumbers, squash and melons under certain circumstances.182

● CALCIUM ARSENATE: Where calcium arsenate is recommended it rarely can be substituted for with lead arsenate. Under most conditions, do not use calcium arsenate on beans.

● CALCIUM CYANAMID: When using calcium cyanamid fertilizer in powder form for weed killing, it is most effective when weeds are small and covered with a film of moisture. Heavy dew, still air followed by a warm bright day, are needed for satisfactory results.

● COPPER FUNGICIDE: When copper fungicide is recommended sulfur should not be used.

● CRYOLITE should never be combined with bordeaux or with lime. Properly prepared cryolite dusts are available through most dealers. Corn should not be sprayed for weed control just before or after silking or pollination. 164

● CHLORDANE: Never use chlordanes in combination with alkalies —they are not compatible.

● DINITRO SPRAYS: Do not spray any crop when the plants are wet from dew, fog, or rain or when the soil surface is especially wet; also, do not spray under conditions of excessively high humidity or when rain is expected within 24 hours following applications. Make sure sufficient time is allowed for the spray to dry on the weeds before dew starts to form. Spraying should not be done immediately after a long cloudy period, but should be delayed until there have been one or two days of sunshine. Do not spray in late afternoon when it is likely to become cooler. When temperature is over 80°F or very humid, use the lower amounts. 136

● DN 289: Do not use DN 289 on peaches. 168

● **DN 111 may be injurious to fruit or foliage if used when temperature is above 90°. It may also cause injury if used with oil sprays.**

● **DDT: Do not use DDT with miscible oil sprays.** 168 **DDT may be used with most common fillers or carriers, but mixing with alkaline materials should be avoided, especially hydrated lime and clays. DDT may result in injury to the foliage of such cucurbits as squash, cucumber, melons and tomatoes.**277

● **EMULSIONS: On very tender plants use emulsion rather than oil which tends to burn easily.**

● **FERBAM may be substituted for bordeaux mixture or hydrated lime but must *not* be used in combination with either nor should it be used within a week before or after using bordeaux mixture. Do not use ferbam with miscible oil sprays.**168 **When using ferbam or DDT with oil *always add oil last* just before the tank is completely filled with water.** 168

● **IPC: Isopropyl-N-phenyl carbamate is not very soluble in water. Some commercial preparations come in the form of wettable powders. These may be applied in suspension provided enough water is used, the suspension is kept well agitated, and the spray pressure is around 100 pounds. Do not attempt low-volume application of the suspension.**

● **LEAD ARSENATE: When lead arsenate is recommended rarely can it be substituted for by calcium arsenate.**

● **LIME SULFUR: Do not apply lime-sulfur when temperatures are above 90 degrees.**

Do not use sulfur with oil. Never spray oil within 10 days of the last sulfur. 168 ***Sulfur* is very damaging to canteloupe.**

● **ONIONS must not be sprayed while wet with dew.**

● **PARIS GREEN should not be used on the foliage of fruit bearing trees.**

● **PEAS AND FLAX: Do not spray peas and flax with dinitro if wet. Where dinitro selectives are being used on peas and flax, the plants should not be sprayed when wet with dew, fog, or rain, or when the humidity is very high. Increased wetting of the crop under these conditions may result in serious injury. When dews are heavy in the evening, lasting into the morning, limit spraying to midday.**

With oils, moisture on the plants is less serious. The spray usually blows off most of the water, and oil will wet the waxy cuticle of plants even if a thin film of moisture is left. With 2,4-D, excessive mois-

ture in the plants at the time of aplication may dilute the spray and lower its effectiveness. Rainfall a few hours after 2,4-D spraying may not impair results, particularly when susceptible plants such as wild mustard and radish are being treated. Warm weather tends to hasten absorption of 2,4-D. 5

● PARATHION: Do not apply more than ½ pound 15 percent wettable powder in 100 gallons of water to McIntosh and related varieties such as Cortland, Macoun, Kendall, Melba, etc., Golden Delicious or Jonathan apples, because fruit injury can result from higher doseages under certain conditions. Foliage injury can also result from sprays before first cover of more than 1 pound 15 percent wettable powder in 100 gallons of water to McIntosh and related varieties. Consult county agent or experiment station. Under some conditions of high temperature and drought some injury has occured on Bosc pears in the northeast. Do not prune trees or thin fruit in dense orchards until a reasonable time (at least two weeks) has been allowed for dissipation of vapors from residues. Do not apply parathion sprays or dusts to cucurbits unless plants are dry and until runners begin to form. 160

● PYRETHRUM: Never substitute pyrethrum or nicotine for lead arsenate.

● ROTHANE cannot be used with oil as a sticker on small fruit. Western Washington experience shows that when oil is used raspberries develope a chlorosis. If treatment is repeated several times the condition becomes chronic and the injury may be severe according to E. P. Breakley and Carl Johansen. 105

● SUMMER OILS with sulfur are usually injurious to foliage.

● TOXAPHENE RESIDUE: Toxaphene retains its killing power for several weeks after treating crops for grasshoppers. This is a distinct advantage so far as grasshopper treatment is concerned. If such residue is harmful to animals or to humans when stored in the fatty tissue of beef or lamb, another problem arises. The results of investigations made by the Montana State College of Agriculture, Experiment Station and reported in Circular 461 in June 1949, indicate that no significant amounts of toxaphene are present in beef or lamb when recommended rates of application (1½ pounds per acre) were used. 253

Under most conditions do not use toxaphene on melons.

● TEPP: Under most conditions do not use tepp on tomatoes.

● WETTABLE POWDERS tend to clog spray nozzles and wear out pumps. Oil emulsions and oil or water solutions are much less susceptible to clogging.

● 2,4-D When planning the use of *esters* on hot dry summer days consider the *high* volatility of the ester. Under some conditions the active ingredient may vaporize before reaching the plant. Not only does the crop receive no benefit but adjoining crops may be damaged by the vapors.

● RELATIVELY SAFE FORMS OF 2,4-D: The *ester form* of 2,4-D in oil gives the least margin of safety due to the problem of getting it on uniformly. *Esters* in water are said to offer a 4 to 1 margin of safety over the use of esters in oil. Amines in water are said to offer an 8 to 1 margin of safety over esters in oil. A pilot, therefore, must be extremely accurate in knowing exactly where he is laying each swath to avoid overlap and skip when using ester in oil.

● CASES ILLUSTRATING THE MISUSE OF 2, 4-D: Here are some incidents of improper control in the applying of 2, 4-D as given before the 1949 Western Weed Conference: 1885 acres of mature barley in the San Joaquin were sprayed by airplane with 2, 4-D ester to dry up wild lettuce. Large cotton acreages adjoined the barley field. Most of the damage occured close to the barley field but traces of damage were found at 21 miles, marked symptoms at 15 miles. In each area every cotton plant was equally distorted and depressed. The behavior of the ester form is unpredictable.

Another example of damage from ester form of 2, 4-D is the damage which occurred to a cotton field beside an airport where used containers of ester 2,4-D were stored. Just the fumes from these containers was enough to do damage.

At Fresno, California empty barrels that had contained pure 2,4-D acid were hauled to a dump near the city for disposal with specific instructions that the containers be buried. Instead they were burned. In a few days pronounced injury was found in adjacent cotton fields lying in the path of the prevailing wind. The pure acid was volitized by the heat.

In the Old River section of the San Joaquin a field infested with Russian knapweed was sprayed with 2,4-D. Cotton was being replanted in an adjoining field because of wind erosion. Wind storms were frequent during the spring and summer. It is believed that the wind picked up particles of dust impregnated with 2,4-D and carried it to the adjoining cotton.

Horse nettle and Russion knapweed are very hard to injure with 2,4-D. 165 Other chemicals are probably more effective. Legume seedlings are easily killed by 2,4-D. It should therefore not be aplied to small grains early in the season if a legume has been seeded. Later as the small grain grows taller, it gives more protection to the legume, and 2 4-D may not reduce the legume stand excessively. 164

For the Safer Use of 2,4-D

★ Do not use weed control equipment for applying insecticides, fungicides or fertilizers.

★ 2, 4-D may damage desirable plants, such as cotton, vegetables, flowers and other ornamentals. Extreme care should be used to prevent the chemical from reaching them through drifting, leaching into the soil, running surface water, irrigation water and other ways. Coarse sprays are less likely to drift and should be employed.

★ Avoid accumulation of excess quantities of 2, 4-D on the skin or in the clothing. It can be removed readily in both cases by washing with soap and water.

★ 2, 4-D products should be stored separately from fertilizers and seeds, and from other pest control products such as insecticides and fungicides. Containers of 2, 4-D should be kept tightly closed during storage.

★ Vapors from 2, 4-D products, especially ester formulations, may injure susceptible plants in the vicinity. 135 The same precautions used in handling 2,4-D apply to handling 2, 4, 5-T

★ Creeping bent grass and buffalo grass are injured by 2, 4-D. 165

★ 2,4-D is particularly injurious to cotton, tomatoes, potatoes, beans, peas, tobacco and grapes.

The combination of 2, 4-D *ester and diesel oil* has proven itself considerably more dangerous to use on crops since the over-doses as a result of poor distribution did result in more damage than where esters or amines in water were used. When oil is the carrier it must be used much more carefully than water. 157

Chemicals Dangerous to Human Beings

Since most materials used for pest control are toxic to some extent and some highly critical to human and animals, it is important to keep them away from children, irresponsible adults, and animals. Unused material should always be kept in the original container with attached label.

If poisoning occurs, call a physician at once, but before his arrival the victim may often be saved by prompt first-aid treatment. If the harmful material is on the skin or in the eyes, wash off with plentiful amounts of water and remove contaminated clothing. If the poisonous material is not known, a useful general antidote is a mixture of the following: 1 tablespoon of magnesia, 1 tablespoon of tannic acid or hydrated iron oxide, 2 tablespoons of finely divided wood charcoal. Stir together in water and give a small amount at intervals. Watch for signs of failure to breathe, and apply artificial respiration if needed.

Antidote Formulas

The emetics, demulcent drinks, stimulants, and sedatives mentioned in connection with the specific antidotes may be prepared as follows:

● EMETICS. Mix from 2 to 4 teaspoons of mustard in a cup of warm water and stir to a thick cream, or give from 15 to 30 grains (1 to 2 grams) of powdered ipecac in water; repeat every 10 to 15 minutes.

● DEMULCENT DRINKS: Flaxseed or slippery elm tea, barley water, thin starch, water, milk, white of eggs mixed with water, or thin flour paste, give any of these very freely.

● STIMULANTS: Put from 10 to 20 drops of aqua ammonia in half a glass of water; or put from ½ to 1 teaspoon of aromatic spirits of ammonia in ½ glass of water; give for one dose and repeat as needed. Strong tea or coffee also are useful..

● SEDATIVES: Give from 1 to 2 tablespoons of paregoric in ½ glass of water; or give 30 grains (2 grams) of potassium bromide in water for a dose and repeat as required. 60

Materials Injurious to Humans

★ Entry through the *digestive track.* Avoid smoking while working with dangerous materials, keep cigarettes from becoming contaminated, maintain strict hygiene, change all clothing, bathe freely, wash hands carefully before eating. (Water solubles are the most dangerous.)

★ Entry through *inhalation.* Always work up wind from the material. Eliminate the source if possible. Use a less toxic material if possible. Use convenient size package for mixing.

★ Avoid *horseplay.* Serious accidents have occured quite innocently through play. Don't take chances when working around others.

★ Sodium chlorate is highly *combustible.* Avoid getting it into clothes and shoes.

★ All respiratory devices have *limitations*. Know what they are. Canasters for example, are good for only a limited number of hours. Canasters are designed to take out only certain elements, they therefore cannot be used indiscriminately. See Fig. 12.

★ Handkerchiefs over the nose and mouth are of *little* value. Many injurious chemical vapors go right through the cloth.

★ Always keep two persons on the job when working with injurious materials. Buy only respirators which are approved by the U. S. Bureau of Mines.

Toxicity of Commonly Used Insecticides

COMPOUND	LOCAL EFFECT	Predominant SYMPTOMS	ESTIMATED FATAL DOSE	PERIOD
Rotenone	Irritation	Stupor, frequent convulsions, respratory depression, death.	Grams 200	2-3 days
Pyrethrine	None	Incoordination, tremors, muscular and resiratory paralysis, death.	100	3-5 days
Nicotine	Irritation	Tremors, convulsions, curare-like paralysis, death.	0.060	Minutes
Lethanes	Irritation	Deep depression, dyaanosis, dyspnoea, toxic convulsions, respiratory paralysis, death.	28-70 of concentrates.	Within 12 hrs.
DDT	None	Giddiness, nervous tension, involuntary muscular	30	2-24 hrs.

COMPOUND	LOCAL EFFECT	Predominant SYMPTOMS	ESTIMATED FATAL DOSE	PERIOD
		tremors, convulsions, depression, respiratory failure, death.	Grams	
Methoxy-chlor	Slight Irritation	Questionable tremors, depression.	450	2-4 days
TDE	Slight Irritation	Lethargy	300	1-4 days
Chlordane	Irritation	Convulsions, depression repeated several times, deep depression, death.	5-60	1-4 days
Toxaphene	Irritation	Epileptiform convulsions and death.	7	4-24 hrs.
Benzene	Irritation	Hyperirritability to outside stimulus, occasionally convulsions, depression, death.	30	1-5 days
Organic phosphates	Irritation	Lacrimation, salivation, sweating, nausea, vomiting, diarrhea, resiratory distress, disturbance of vision, headache, muscular tremors, generalized colapse, death.	0.012	1-4 hrs.

●ALDRIN: Both compound 118 and Compound 497, as well as insecticidal formulations containing these compounds, should be handled with extreme care, both by the formulator and by the ultimate user. In this connection, it is most important that contaminated clothing or contaminated skin be washed to prevent the continued contact of these materials with the skin.

Courtesy Acme Protection Equipment Co.

Fig. 12. Acme full-vision No. 6, face piece type respirator.

In formulating plant dust, inhalation must be avoided by proper ventilation facilities, and in application the wearing of dust respirators must be enforced. The important difference between these two chemicals is that of much higher vapor pressure of Compound 118 with an accompanying higher rate of volatility and a very marked residual property commensurate with a much lower vapor pressure in the case of compound 497. 192 Aldrin must be used with extreme caution untill such time as its toxic effect on warm blooded animals is determined.

● AMMONIUM SULFAMATE: Avoid getting any pray solution of ammonium slfamate into the eyes. Prolonged contact with the skin should be avoided, particularly if the solution is strong.

● CRYOLITE is poisonous to humans and higher animals as well as to insects. It should be used and stored with appropriate precautions. The treatment of vegetables should be so regulated that those parts to be eaten do not carry a poisonous residue. Application of this material to vegetables, the leafy portion of which is soon to be eaten, is not recommended. 167

● DDT: From the available facts and opinions of scientific workers there have been no deaths due to DDT poisoning up to the present and that there is likely to be none unless proper precautions are disregarded. Those who are working with DDT should use rubber gloves, protective clothing, respirators and ventilating equipment if indoors. Residues sould be removed from the skin by soap, water and brush. Because of the possible cumulative effects, those who are working continuously with it should be subjected regularly to urine examinations to determine if they are absorbing any substantial quantity.

● DIELDRIN: The toxicity of dieldrin has not yet been determined. It should therefore be handled with extreme precaution.

● DOW SELECTIVE WEED KILLER (DINITRO): This product is flammable. It should be kept away from heat and open flames. No smoking should be allowed where it is being handled. The vapors of this preparation are harmful, and care sould be taken to avoid breathing them. The material can be absorbed through the skin in taxic quantities; therefore, contact with the skin should be avoided. Oil resistant rubber gloves should always be worn while handling or mixing If the material should be spilled on the skin, it should be promptly removed by washing with soap and plenty of water. Significantly contaminated clothing should be removed and washed before it is re-used. Dow Selective Weed Killer may stain silk, wool, hair and skin. 136

●ETHYLENE DIBROMIDE is toxic to man even in dilute form, and should be handled accordingly. While there may be little danger out-of-doors, care should be taken not to breathe the vapor.

Severe irritation to the skin may follow prolonged exposure. Wet clothing should be removed immediately. If spilled on the skin, the exposed surface should be washed immediately with soap and water. 105

Vapor of ethylene dichloride has a slight anesthetic action if inhaled. No harmful effects are likely, however, unless exposure is over a prolonged period and at high concentrations. In preparing the emulsion, the work should be done out-of-doors or in a well-ventilated room at temperatures between 50 and 80 degrees F. Both the emulsion and the liquid ethylene dichloride itself should be kept away from fire or an open flame. 105

● EPN was reported in the recent Food and Drug Administration hearings as being 2 to 5 times less toxic than parathion.

● GENERAL CHEMICAL FORMULA 7 AND 7B-D: Formula 7 or 7B-D may irritate skin and cause burns upon prolonged contact. Avoid contact with skin and eyes. In case of contact, wash off with plenty of water. Formula 7 and Formula 7B-D are non-toxic to live stock and do not appeal to cattle. 145

● METHOXYCHLOR is said to be only slightly irritating when applied to the skin. It is doubtful whether an individual would swallow enough to produce any toxic effect. The estimated fatal dose for man is said to be in the neighborhood of 450 grams (1 pound) if consumed at one time.

● MERCURY COMPOUNDS are extremely poisonous even in very dilute solutions. If it is accidentally swallowed, give whites of several eggs at once. The stomach should then be emptied as soon and as completely as possible and eggs, starch or flour paste swallowed liberally until a physician can be called. Do not leave material or empty containers around where children or pets have access to them.

● POTASSIUM CYANATE: This is not a very poisonous compound, but it should be handled with care. Do not leave the solution, or empty containers, where children or pets have access to them. Follow all instructions and precautions printed on the label. 5

● PMAS contains 10 percent phenyl mercuric acetate held in water solution by an organic complex. It can be spilled on the hands, and no injury will result if rinsed off with water immediately. However, if PMAS is left on the skin, painful blisters may develop a few hours later. These should be given the same treatment as blisters caused by heat.

The precautions needed with PMAS are no different than those required with strong acids, arsenicals, other mercurials or caustic soda. PMAS, like these materials, becomes much safer on dilution with water. In any applications where the solution is expected to come in contact with workman's hands, it should be diluted at least 1:100. This will prevent discomfort and burning of the skin. 170,

● ROTENONE is very poisonous to *cold blooded* animals, although harmless to warm blooded animals and man. Will cause a numbness of the tongue, lips and throat of the person handling it when exposed continuously. This numbness disappears in about two hours.

● ROTHANE results in slight skin irritation and general lethargy. The fatal dose is about ten times that of DDT or about 8 to 10 ounces of solid material.

● STODDARD SOLVENT is an inflammable as kerosene. A fire extinguisher should always be kept handy.

● SULFURIC ACID: Always wear rubber gloves and goggles when handling the concentrated acid. Have a supply of carbonate of soda solution handy to wash off any concentrated acid that spills on the skin.

● TCA when in prolonged contact with the skin may produce painful irritation and pealing of the skin. TCA can be washed off easily, other possible toxic effects of TCA are not known at present due to the newness of the herbicide. Wear rubber gloves when handling sodium trichloroacetic by hand.

● TETRAETHYL PYROPHOSPHATE (TEPP) AND PARATHION: These insecticides are poisonous if *swallowed*, *inhaled or absorbed*. Tetraethyl pyrophosphate is said to be 125 times as toxic as DDT. Pilots report that fumes of the insecticide drift into the cockpit and affect vision. This material is readily absorbed through the skin. Six hundred mg. is estimated to be a fatal dose to the human being. On repeated application this dose is halved.

1. Avoid contact with the skin. (Use natural rubber gloves which are impervious to tetraethyl pyrophosphate. Never synthetic, leather or cloth.)

2. If skin is accidently contaminated, wash thoroughly with soap and water immediately.

3. Keep shirts buttoned at neck and sleeves.

4. Avoid inhaling tetraethyl phosphate by wearing a respirator or or mask approved by the U. S. Bureau of Mines.

5. At the end of the operation, remove clothing and bathe thoroughly with warm water and soap.

6. Avoid contamination of food. Wash hands before eating.

7. Avoid smoking, eating, and chewing tobacco in the operation areas.

8. Permanently dispose of all containers so that they cannot be used for other purposes.

9. Wear a plastic raincoat and plastic rain hat. Clothing that has become contaminated should be removed immediately and washed in soap and water.

10. Any person developing symptoms of headache or tightness of the chest when using tetraethyl pyroprosphate should be removed from the exposure. In the case of ingestion of tetraethyl pyrophosphate an emetic, such as mustard or warm soapy water, should be used immediately and the patient referred to a physician.

11. Atropine described on the box, has been found a physiological antidote but should be administered under medical supervision.

12. Do not store parathion near food or feed products.

Manufacturers recommend that persons susceptible to tepp be removed from the job whenever there is tightness of the chest, painful vision or nausea.

Case Histories of 3 Parathion Deaths

There have been six deaths in the United States during 1949 resulting from exposure to parathion. Three of these occured in industrial plants and three while applying it in the field. In light of these fatalities, growers are urged to exercise extreme caution when using parathion or *tepp*. Both insecticides are hazardous if absorbed through skin by contact, by inhaling dusts or vapors, or by accidently swallowing some of the insecticide. On the other hand, parathion residues on fruits are not known to be a problem if applied 30 days before harvest. *Tepp* apparently presents no residue complications.

Evidence on hand indicates that one big danger is CARELESSNESS while placing parathion wettable powders into the tank. Other possible sources of danger are uncontrolled drifts, contact with skin while spraying or dusting, or insufficient ventilation in rooms where parathion is stored or mixed. 58

● SYMPTOMS: Symptoms observed in humans consist principally of headache and dizziness followed by nausea and vomiting. Other symptoms, such as uncoordinated movements, faulty speech, and impaired vision due to constriction of the pupils, may also occur. When these symptoms are noticed, cease spraying and *consult a physician immediately*. Tell him to (1) administer atropine grains 1/60 to 1/30 every hour until pupils dilate. (2) clear chest by postural drainage and (3) give artificial respiration if patient becomes unconscious.

A grower intending to use parathion or *tepp* should secure a prescription from his physician for atropine tablets 1/120 grains to use should symptoms of poisoning occur. *Do not use this drug before exposing yourself to these phosphates.* Use *after* definite symptoms occur. 58

Here are the three cases, listed by the American Cyanamid Company after careful investigation, and they should be *must* reading for every user: "In the course of using more than half a billion gallons of parathion spray solutions and large quantities of parathion dusts the 1949 season, three fatal accidents occured in the field. A review of these accidents is given since we feel a full knowledge regarding the circumstances and causes will be beneficial in emphasizing unsafe practices which must be avoided in the handling of parathion and in pointing the way to prevent recurrences.

● CASE NUMBER ONE: William Furnace of Clayton, North Carolina, using a mule drawn cart sprayer in a tobacco field, applied parathion at the rate of 4 pounds of 25 percent wettable powder per 100 gallons of water. That concentration is four or five times the recommended dosage. The operator walked behind the sprayer, one nozzle of which was so arranged that it was level with his face and only about

14 inches away. He used no respirator or other protection and inhaled spray mist all day long. His clothing became soaked with spray. According to reports, he had not been advised of the danger involved.

● CASE NUMBER TWO: Keith Hughes, University of California, applied parathion to citrus with a speed sprayer at the rate of 10 pounds of 25 percent wettable powder to 500 gallons of water. The parathion which he was using was experimental material packed in 50 pound drums. The speed sprayer was loaded 17 times during the day. When this operation was observed on two occasions, the wettable powder billowed up into his face each time. This man wore no respirator or other protection and apparently inhaled considerable quantities of the powder all day. He changed clothing during the lunch hour, although he had not been exposed to excessive spray drift earlier that day. Although he complained of a headach at noon, this was not severe. Returning to the spray operation after lunch, he wore coveralls in addition to a cap, boots and gloves.

Shortly after 4 p.m. this man informed his co-worker that he felt dizzy. A few minutes later he became nauseated, vomited, and left for home immediately. On his way home, he became violently nauseated and had to ask another young man to drive him home. He reached home at approximately 4:45. Fire department personel administered oxygen prior to the arrival of a physician. The doctor arrived shortly after 5 o'clock, but the man was dead at approximately 5:05 p.m.

In this case, continued exposure at the time the wettable powder was added to the spray tank may have been mainly responsible for his death. Although this man had previously worked with parathion and other organic phospates, there were no indications that he was particularly sensitive to these materials. Familiar with the hazards involved, it is not believed that he was knowingly careless in handling the parathion.

● CASE NUMBER THREE: Cecil Pendarvis, Lake Placid, Florida, engaged in loading speed sprayers with 6 pounds of 25 percent parathion wettable powder and 50 pounds of wettable sulfur to 500 gallons of water. This man had previously become sick and had been warned to be more careful. He stirred the material with his bare hands to help force it through the screen. No respirator protection was used. He had gross skin contact and inhalation of the wettable powder."

All three fatalities followed a prolonged inhalation of parathion and prolonged skin contact. All three accidents could have been prevented, first, by better understanding and observance of very necessary precautions and, second, by prompt, adequate medical treatment.

Take this precaution before using parathion: Atropine is the emergency antidote for parathion poisoning and is obtainable only on a doctor's prescription since it also is a strong poison. The doctor in your neighborhood should be informed regarding the symptoms of parathion poisoning and the treatment shown below. Consult your doctor and arrange with him for a prescription of atropine grains 1/120 (0.5mg.) to be kept on hand for emergency use. Never take atropine or any similar drug until *after* warning symtoms appear. The symptoms of parathion poisoning include headache, blurred vision, weakness, neusea, cramps, diarrhea and discomfort in the chest. If you feel any of these symptoms while using parathion, quit work, take two atropine tablets at once, and go to a doctor. Do not use parathion or other organic phospate insecticides until your doctor has examined a blood sample for parathion effect (until regeneration of blood and tissue cholinesterase is complete.)

Respirators absolutely must be used when loading and mixing parathion.

● 2,4-D: All available evidence shows 2,4-D to be harmless to animals and man. Cattle, sheep, and horses showed no ill effects after grazing on sprayed vegetation. A cow was fed more than 1 pound of 2,4-D during a 6 week period with no ill effect on health, appetite, or milk flow, and no 2,4-D could be detected in the milk. Certain plants may have a peculiar attraction for livestock when sprayed with the chemical. Some ill effects may be expected from spraying poisonous plants with 2,4-D and thus increase their palatability to livestock.

Several persons have experimentally eaten small quantities of 2,4-D over a period without ill effect, and no authentic instance of human poisoning has been reported. In an extremely rare case a person having a peculiar sensitivity to various phenol compounds may find 2,4-D somewhat disagreeable. If concentrated solutions are accidentally spilled on the skin, wash it thoroughly with soap and water. Health authorities say that inpurities in mixtures containing 2,4-D might prove harmful.

● TEPP: Pilots need a full face mask which can be conveniently worn with goggles. The following paragraphs are taken for a report issued by the United States Department of Agriculture, Bureau of Plant Quarantine on the use and characteristics of respirators.

NOTE: the respirators listed are recommended for field use with parathion but are *not* adequate for pilot use. New models fully qualified are said to be in process of manufacture. However, no information is available at this writing. See list of manufacturers in Volume Six.

It has been demonstrated that inhalation of tepp and parathion dusts or mists must be avoided. No suitable, fully effective device available for field use will give complete protection. Several commercially-available respirators have been tested against dust, mists and vapors of parathion and found to possess good filtering characteristics. While these respirators are not completely effective in stopping the materials they will, if properly used and handled, provide a very high degree of protection from field use inhalation hazards.

The purpose of this statement is to characterize briefly respirators which have been tested for efficiency and to specifically indicate commercially-available respirators that have, following detailed test of an appropriate sample device, exclude a high precent of dust, mist and vapor and thus greatly reduce inhalation hazard. If other respirators are tested and prove to give comparable protection, supplementary advice will be distributed. In the meantime, it is urged that operators use only those specific types of respirators that have been tested, in the Department of Agriculture, and found to greatly reduce inhalation hazard. In using respirators the directions and restrictions must be followed in detail.

The commercially-available respirators listed below, when tested with the cartridges and filters specified, gave high degree protection from dusts, mists and vapors of parathion likely to be encountered in field use. The various units were tried on a number of people, and, after making appropriate adjustments of the headstrap, the seal on the face was suitable and tight.

★ American Optical Company respirator No. 5055 equipped with R-55 filter and cartridge unit. Two units attached to each face piece. (American Optical Company, Southbridge, Mass.)

★ Chicago Eye Shield "Healthguard Respirator" style 95 equipped with "Code B" cartridge and filter 1000 or 1001. One unit attached to face piece. (Chicago Eye Shield Company, 2300 Warren Boulevard, Chicago, Ill.)

★ Mines Safety Appliances "Comfo" respirator equipped with filter and cartridge unit. Two units attached to each face piece. (Mine Safety Appliance Company, Braddock, Thomas & Meade Streets Pittsburg, Pa.) This is comparable with the respirator formerly distributed by the American Cyanamid Company.

★ Pulmosan DC 5100 Aluminum Body respirator equipped with DMA Cartridge and MN-500 or P-7 filter. Two units attached to face piece. (Pulmosan Supply Equipment Corporation, 644 Pacific Street, Brooklyn 17, N. Y.)

★ "Willson Agrisol Dust and Vapor Respirator" equipped with R414 filter and "11-A Agrisol" cartridge. Two units attached to face piece. (Willson Products, Inc., Reading, Pa.)

Respirators equipped with the filters and cartridges listed above should NOT be used to provide protection from mists, vapors, or dusts containing tetraethyl pyrophosphate or hexaethyl tetraphospate.

In the use of respirators the following practices are highly important:

1. Change filters twice a day, or oftener should breathing become difficult.

2. Change cartridges after 8 hours of actual use, or oftener if any parathion odor is detected.

3. Remove filters and cartridges and wash face piece with soap and water after use. After washing, rinse thoroughly to remove trace of soap. Dry face piece with clean cloth, uncontaminated with parathion. Place face piece in a well ventilated area to dry.

4. Store respirator, filters, and cartridges in a clean, dry place—preferably in a tightly closed paper or cellophane bag.

Respirators do not provide needed protection from inhalation of *parathion* dust, mist, and vapors for use by:

1. Airplane pilots.

2. Those formulating or mixing insecticides in closed spaces.

3. Those applying insecticides, including aerosols, in greenhouses.

ANTIDOTES FOR SPECIFIC POISONS

● ALKALIS (SODIUM OR POTASSIUM HYDROXIDE, LYE, STRONG AMMONIA: Wash off with plenty of water, then apply vinegar or lemon juice. If swallowed, give milk, or orange juice.

● ARSENICAL COMPOUNDS: Give an emetic, such as mustard water, and a mixture of milk of magnesia and iron oxide. After vomiting has occured, give egg white or other demulcent drinks freely.

● CARBON DISULFIDE, CARBON TETRACHLORIDE, METHYL BROMIDE: Get the patient into fresh air at once and give an emetic if the poison has been swallowed. Keep the patient warm and give mild stimulants unless there are convulsions. Delayed effects from methyl bromide are especially dangerous.

● CRESOL, CRESYLIC ACID, CARBOLIC ACID, PHENOL: If external, flood with water, then apply a bland oil, such as olive oil or cotton seed oil. If swallowed, give milk or other demulcent drinks, then an emetic.

● COPPER COMPOUNDS: Give an emetic and baking soda, milk or lime, or thiosulfate solution. After vomiting has occured, give demulcent.

● MECURIC CHLORIDE (CORROSIVE SUBLIMATE): Give egg white and milk in large quantities. Then give water containing baking soda or animal charcoal, and induce vomiting. Since this poison is extremely dangerous, treatment should be started at once and the patient taken to a hospital as soon as possible.

● CYANIDE: Poisoning in the course of insect control usually occurs because hydrogen cyanide gas is inhaled. Get the victim to fresh air, keep him warm, and give artificial respiration if needed. Ammonia or smelling salts are the best stimulants. Since cyanide gas kills very quickly or else the victim almost invariably recovers, first-aid must be given very soon or it is of little use.

● FLUORIDES (FOR EXAMPLE, SODIUM FLUORIDE): Give lime-water, then an emetic, followed by demulcent drinks.

● NICOTINE: Give an emetic then strong tea or coffee. Keep the victim warm.

● TARTAR EMETIC: Give an emetic, then strong tea, followed by demulcent drinks. Keep the victim warm. 60

● MERCURIC COMPOUNDS: If accidentally swallowed give whites of several eggs at once and call a physician. Stomach should then be emptied as completely as possible. Swallow eggs, starch or flour paste liberally until a physician arrives.

● SANTOPHEN 20: In case a solution of Santophen 20 is accidentally swallowed, vomiting should be induced by administering mustard and water, or other emetic, and a physician called. "Sneezing" is likely to occur when Santophen 20 is handled, but the nasal irritation is minor. A respirator or folded gause pad over the nose and mouth may be worn if Santophen 20 dust causes sneezing or coughing.

Wash hands and face with soap and warm water after handling. Both the solid material and its solutions are irritating to the skins of most individuals if contact is prolonged beyond five or ten minutes, or if repeated contacts for shorter periods of time occur, depending on the solvent used.

In preparing and handling Santophen 20 solutions, care should be taken to avoid getting either the solid material or its solutions in the eyes or on the skin. Clothing should not be allowed to become saturated with the solution. 101

● DDT—In case of acute DDT poisoning:

1. Call a physician.
2. Wash out the stomach thoroughly (Give warm, soapy water, salt or baking soda in warm water.

3. Give a saline—not an oil—laxitive.

2. Give wrethane as long as necessary in dosage sufficient to control the nervous symptoms.

Acute DDT poisoning such as might accompany the swallowing of a large amount of DDT would manifest itself first by over excitability, then failure of coordination, tremors, spasams and convulsions.

First Aid for Parathion Poisoning

Remove patient from contaminated atmosphere; keep him under continuous observation. Immediately remove contaminated clothing and scrub skin with soap and water for fifteen minutes. If swallowed, make patient vomit by giving warm salty or soapy water. Don't wait for doctor; give atropine (two tablets) at once if symptoms include vision or pin-point pupils. Keep an emergency supply on hand. Obtain emergency supply of twenty tablets of atropine (1/100 grains each). Prescription required.

● TREATMENT FOR PARATHION POISONING: *Physicians' Note:* Warning symptoms include weakness, headache, chest pain, blurred vision, pin-point pupils, salivation, sweating, nausea, vomiting, diarrhea and cramps.

Treatment: Give atropine preferably by injection, grains 1/100, two or three tablets at once and parenterally or orally every hour as required up to thirty tablets or until pupils dilate. Never give morphine. Clear chest by postural drainage. Give artificial respiration if patient becomes comatose. Oxygen may be necessary. Observe patient continuously forty-eight hours. Repeated exposure to cholinesterase inhibitors may, without warning, cause prolonged susceptibility to very small doses of any cholinesterase inhibitor. Allow no further exposure until time for cholinesterase regeneration has been allowed as determined by blood sample test.

A question aften arises as to the effect on health of consuming small amounts of insecticide residue on fruits or vegetables over a long period of time. The United States Public Health Service has published data on this subject, obtained in one of the principal apple-growing sections of the country. It was found that many of the people who were producing apples lived literally in an atmosphere of lead arsenate, and the insecticide was taken into their bodies over a long period of time and in large amounts—many times the tolerance on food—without harmful effect. 201

Chemicals Injurious to Equipment

Sulfur is extremely inflammable and therefore hazardous to spread by airplane unless handled properly. The FAA makes special pro-

visions for aircraft being equipped for handling sulfur. (See booklet Number Six of the Air-Applicator Information Series for detailed information.)

Dust hoppers have been known to catch fire from exhaust sparks also from static edectricity. Sulfur can be ignited merely from moving the hopper gate to rapidly and causing friction. You can accidentally ignite sulfur while loading it. In the air a sulfur fire allows the pilot only about time enough to jump.

● **AMMONIUM SULFAMATE will corrode certain metals, particularly brass. Equipment must be thoroughly cleaned after each use.**

● **AMMONIUM THIOCYANATE is corrosive to metals, particularly iron but is not harmful to the skin.**

● **CHLORATE materials are corrosive to spraying equipment and should be applied in large gallonages of water, at pressures ranging from 50 to 150 pounds.** 166

● **SULFURIC ACID is corrosive to machinery and will destroy clothing and burn the skin. Special acid resistant equipment is required for its use. Sulfuric acid, in concentrated form, does not attack iron or steel, but the dilute spray solution is corrosive to these metals. This action on metals makes it necessary to use acid-resistant spray pumps and tanks, or inexpensive equipment which may be discarded after one or two seasons' use. All-brass pumps, or other resistant metals, rubber-impeller paddle pumps, and wood or lead-coated spray tanks are required for continued use of dilute acid spray. The following precautions should be observed in handling sulfuric acid:**

1. **Always pour concentrated acid *into water*, never the reverse process.**
2. **Do not use acid in galvanized equipment.**
3. **Avoid contact of acid with shoes and cotton clothing.**
4. **Wear rubber gloves when handling concentrated acid.**
5. **Keep a container of bicarbonate of soda available to neutralize acid which may be accidently spilled on clothing and skin. In case the skin is burned by acid, wash quickly with water and apply bicarbonate of soda.** 63

● **TCA: Sodium salt of TCA acid is approximately neutral but the *ammonium* salt is acid and corrosive. Application equipment should be cleaned thoroughly after use to prevent rusting. Wear rubber gloves when handling TCA.**

● **PMAS: Equipment used to spray PMAS should be rinsed out with water after using.**

INFLAMABLE CHEMICALS

● SODIUM CHLORATE can be handled safely by preventing it from coming in close contact with burnable material. Most chlorate fires arise from getting a burnable material in contact with a solution of sodium chlorate then letting the material dry. Any spark may then cause a fire. Chlorate fires cannot be smothered; they must be put out with large amounts of water. Clothes which have come in contact with chlorate and then become wet are a serious fire hazard unless they are thoroughly washed before drying. *All chlorates should be handled with great care to prevent serious accidents.* 116.

● SODIUM AND POTASSIUM CHLORATE are highly explosive. Clothing and vegetation which has been sprayed with these solutions then dried are inflammable.

● DINITROS are inflammable under many conditions. No smoking should be allowed around this material. It imparts an indelible yellow stain to clothing and skin.

● SODIUM CHLORATE AND ATLACIDE: There is a fire hazard in connection with the use of sodium chlorate and altacide, particularly pure sodium chlorate. *Precautions should be taken to mix these chemicals in or near buildings and not to spray the chemical on organic matter, such as straw, trash, or clothing and shoes.* These materials may be ignited by a spark or by friction. Clothes which have had chlorates spilled on them and have been allowed to dry should not be worn before they are washed. 111

● CARBON BISULFIDE is a heavy, highly volatile, and inflammable liquid. It vaporizes rapidly into an extremely toxic gas which is heavier than air. Care should be exercised to keep it away from flames or sparks, since the vapor is inflammable and when mixed with air is explosive. Smoking by those handling carbon bisulfide should be prohibited. The fumes should not be inhaled. 111

Chemicals which are Hazardous to Animals

When using materials which are known to be lethal to bees, livestock or other property, one should exercise every precaution to protect all property from damage and, as a means thereto, use only such methods of application and under such climatic conditions at the time of application as shall confine the material to the premises of intended application so as not to cause appreciable loss to bees, livestock or other property on adjacent premises. As a further precaution, it would be desirable when applying materials which might drift onto property of others in quantities that might be destructive to bees, animals or other property, to notify your neighbors or interested parties sufficiently in advance of the time of application as to safeguard your interests as well as theirs.

● SODIUM CHLORATE is not particularly poisonous to stock, however, when taken in large quantities may kill animals. Chlorates are salty in taste and attractive to stock. Adequate salting of the stock will materially reduce the amount they may eat. Stock which have been properly salted are seldom bothered by chlorate poisoning. Even though normally avoided by livestock, *poisonous plants become attractive* to them when treated with sodium chlorate. Properly distributed applications made to bare soil are reasonably safe but stock should be excluded from the treated areas until at least one heavy rain has fallen to be certain no poisoning will occur. Chlorates should be covered and empty containers should be properly disposed of to prevent possible accidents. 116

● TOXAPHENE: The Hercules Powder Company, makers of Technical Toxaphene suggests these precautions: Toxaphene, like most insecticides, can be poisonous to man and livestock. The residue resulting from dusting or spraying crops may persist for days or weeks after application. Do not feed forage treated with toxaphene insecticides to dairy animals or to animals being finished for slaughter, and do not apply toxaphene insecticides to those parts of vegetables or fruit that will be eaten or marketed unless residues are removed by washing or stripping. Livestock should not have access to areas where excessive amounts of bait have been deposited through spillage or other means.

● DDT is moderately poisonous to warm-blooded animals. Some of it may stick to the leaves, stems, and husks of corn plants, but when corn is treated according to recommendations, experiments have repeatedly shown that pratically none reaches the kernels. Three to four weeks after proper treatment, corn plants show only about one part per million of DDT. While no ill effects have been noted in animals feeding on crops treated with DDT, it may be deposited in the fatty tissues of animals eating the forage and then be thrown off in their milk. Dairy animals should not, thereore, be fed forage treated with DDT. 163

● ERRORS IN HANDLING GRASSHOPPER BAIT IN 1949: The following incidents illustrate the importance of knowing the hazards of handling any kind of poisonous pest control materials and using full precautions.

An airplane went through a fence knocking it down. Nine cows got into the field baited for grasshoppers. Three died and six were sickened, the result, a $12,000 claim.

A pilot had a forced landing on the range. He dumped his load before taking off and made no report of it. Three cows got sick and one died.

In Wyoming some bait got wet and remained in lump stage, cattle got to it and were fatally poisoned.

Other occasions of improper handling of bait consisted of allowing materials to remain on the ground where mixing or loading stations had been. These spots should be cleaned up and ground remains plowed under.

DO NOT LEAVE INSECTICIDES UNCOVERED OR WHERE
PEOPLE OR ANIMALS CAN GET TO THEM

DO NOT LEAVE EMPTY CONTAINERS WHERE
THEY CAN BE PICKED UP AND USED

CALL A PHYSICIAN AT ONCE IN ALL CASES OF
SUSPECTED PARATHION POISONING
NEVER GIVE ANYTHING BY MOUTH TO
AN UNCONSCIOUS PATIENT.

PART SIX

PREPARATION OF MATERIALS

Raw chemicals canot be applied directly upon plants. The pure or prepared chemical, whether in dry powder form or liquid, is too strong for immediate application and, therefore, must be diluted. Water or oil is used as a diluent for liquid chemicals. Dusts are diluents for the powder chemicals. A further reason for dilution is to give sufficient volume for good coverage.

PROBLEMS

In addition to the problem of *dilution* there is the matter of *form* in which the chemical will be most effective. Spray materials fall into *four* classes:

1. Straight liquids (diluted or undiluted.
2. Solutions of *soluble* chemicals.
3. Suspension of *insoluble* solids.
4. Emulsions of non-miscible liquids.

Diluents are frequently referred to as carriers inasmuch as they act both to dilute and as a neutral carrier providing volume for the active ingredient in the spray or dust. A number of additional problems arise in preparing chemicals for effective application, because many chemicals require the use of *solvents* in order to bring them into solution with water or oil. Liquid sprays are made up in the form of solutions, emulsions and suspensions. Each of these forms has its advantages for certain types of chemicals or particular application requirements.

In addition to the various forms of liquid sprays there is the problem of getting the liquid to *adhere* to the plants. To meet this problem, spreaders and stickers are added to the liquids. Even the water used in sprays presents a problem if it is unusually hard, in which case a *sequestering* agent is required. This prevents precipitation. The following paragraphs described a number of the materials and processes involved in preparing chemicals, sprays and dusts into usable forms for direct application.

Before attempting to understand the various forms of sprays it is well to understand the terms *solution, emulsion and suspension.*

● A SOLUTION is a mixture containing a solvent and a solute (substance which goes into solution when mixed with its solvent). In a solution the substance dissolved does not settle out upon standing.

There are several kinds of solutions. A *dilute solution* is one which can dissolve more of the solvent. An *unsaturated solution* is one which can dissolve more of the solute than it presently contains, for example, a glass of water containing one pinch of salt can easily dissolve and contain several pinches of salt. A *saturated solution* is a solution which contains all of the solute possible for a given temperature and pressure. Any additional substance will not be dissolved, for example, several teaspoons of sugar in a glass of water—part will dissolve and the balance remain in the bottom of the glass.

A supersaturated solution is a solution which holds more of the solute than it normally should. This condition is an unstable one. For example, dissolve a substance such as hypo in warm water (warm water will dissolve more hypo than cold water) cool the solution carefully. The hypo will stay in solution, but shake it and the excess will crystalize out. Dropping a crystal of hypo into the super-saturated solution will accomplish the same results. This is called *seeding*.

A solution normally does not require agitation to keep the solute dissolved. Miscible liquids are those which form true solutions. For example, water and alcohol may be mixed in any proportions and requires no agitation to stay in solution.

● A SUSPENSION is a liquid in which a substance is mixed. Sand and water is an example. To keep the water and sand mixed requires constant agitation. As soon as a suspension is allowed to stand the substance will begin to settle out.

In a solution the particles are so small that they cannot be seen, thus the solution is a clear liquid. In a suspension the particles are observable giving the liquid a turbid appearance. A solution does not settle out on standing, a suspension does. A solution will readily pass through a filter whereas a suspension will not. In a solution the particles are taken up in a definite amount for a given temperature. There are no definite limits on the amount of particles taken up in a suspension. In a solution the particles of solute raise the boiling point and lower the freezing point of the solvent. They have no effect in a suspension.

● AN EMULSION is a mixture of two or more non-miscible liquids. (Non-miscible liquids are those which will not mix and tend to settle when standing). Such liquids form an emulsion when shaken or agitated. Oil and water is a good example of an emulsion, allowed to stand the emulsion rises to the top. Actually one liquid is merely suspended within the other. Add a little soap to the mixture of oil and water and the oil does not separate so easily. The soap forms a protective film over each colloidal particle of oil. The soap is called an emulsifying agent.

Stability

If a liquid and an insoluble, finely ground solid or two immiscible liquid are put together with sufficiently violent agitation, one material will become uniformly distributed within the other, a suspension being formed. Such preparations, however, are *unstable*, and separation occurs soon after the agitation ceases. In order that a uniform mixture may be maintained, a third material, possessing certain peculiar properties, must be present. Such materials are called:

Emulsifying agents: They collect, or are absorbed, at the surface of the solid particles or liquid droplets and prevent them from coming together. Preparations containing an emulsifying agent or emulsifier are said to be *stablized,* though it does not follow that they will remain uniform indefinitely.

When an emulsified liquid, for example, oil, separates from an emulsion, the latter is said to *crack* or *break*. If the oil does not completely seperate but merely rises with the emulsifying agent to form a very concentrated emulsion, it is said to *cream*. this is very easy to put back into the original state, but a broken emulsion is often very difficult to restore. The terms *tight* and *loose* are used to designate varying degrees of stability of either emulsions or suspensions.

When a finely divided, suspended solid material clumps, it is said to *flocculate*, and substances used to prevent this are often called *deflocculators*. Thus some commercial brands of lead arsenate are *deflocculated*—that is, a material is added to the dry powder which will make it easier to keep in suspension in water.

The substances capable of acting as emulsifying agents are extremely numerous. Among those of principal interest with sprays are the soaps (from fatty acids, resins, or petroleum), cresylates, proteins (casein, albumin, gelatin, glue), hydrolyzed starch, flour paste, saponins, and bordeaux mixture.

In application of sprays to solid surfaces, a number of important points need to be considered. If a mechanical mixture of lead arsenate and water is sprayed upon foliage, it will be observed that the mixture draws back from the surface, forms large drops, and rolls off, with the result that an uneven deposit of insecticide is left there. In other words, proper wetting does not occur. To bring this about, a wetting agent or spreader must be included. Such a substance will collect at the surface of the leaves and enable the water to really wet this surface. By increasing the viscosity of the spray liquid, a thicker layer will remain upon the foliage. The purpose served by the wetting agents and emulsifying agents are obviously entirely different, but the conditions are similar and in general the same materials act in both capacities. Thus the emulsifying agents listed above are also good wetting agents or spreaders.

It is not true that the presence of a wetting and emulsifying agent insures the deposit of more insecticide. This is particularly the case with oils, for the coating of emulsifying agent around the oil droplets and wetting agent on the foliage prevent intimate contact of oil with the leaf and may actually decrease the deposit. This is in agreement with the observation that a loose oil emulsion is more toxic than a very tight emulsion.

Experiments have also shown that a mechanically maintained emulsion of oil and water without any emulsifier or wetting agent present is most efficient in control of scale insects from the standpoint of concentration of oil needed. But it is lowest in safety, for each time a region is passed over, additional oil is deposited, with the result that in making sure that all parts of a tree are reached, excessive amounts of oil are left on some parts. By including an emulsifier and wetting agent, this continuous *build-up* is avoided and safety insured. With either oils or other materials, an even *film* coating is much easier to obtain when a wetting agent is used.

Since many leaf surfaces are waxy, mineral oils, which readily wet such a surface are often used as wetting agents with bordeaux mixture, lead arsenate, and other such sprays. Fish oils are sometimes used for the same purpose. Since oils, particularly if of high boiling point, stay on the surface a long time and hold the solid insecticide, they are called *stickers*. The term *fixator* is also used sometimes in describing materials that increase the tendency of spray materials to adhere. 60

CARRIERS

Carriers are usually water or oil for liquid chemicals and various kinds of powders for dust chemicals. Both the liquid and powder types of carriers are discussed more fully in the following paragraphs.

Oil as a Carrier, Penetrant and Sticker

Oil is useful as a carrier, sticker and penetrant for chemicals. Oils hold the active chemical either in solution or suspension. Of all the various types of formulations the oil solution is probably the best for air-application when practicable. The active ingredient is thoroughly distributed throughout the oil and carries insecticide with every drop that hits a plant. A well known example is the use of refined kerosene as a carrier for pyrethrins in fly sprays, in which case the oil has only minor effect, the chemical does the killing. Field sprays, however have been developed recently in which the oil is used for its own toxic effects but the amount needed may be greatly reduced by incorporation of an oil-soluble toxicant. An example is the solution of rotenone in oil for control of various scales on citrus, here the oil as well as the chemical is effetive. The main disadvantage of the oil solution is that it tends easily to burn young foliage.

Oil emulsions have long been used with lead arsenate, bordeaux mixture, and other materials to inrease the adhesiveness of the solid material. 60 When oil is used as an emulsion there is less danger of foliage damage. Oil as a carrier permits the use of the ester form of 2, 4-D. Water as a carrier permits the use of 2, 4-D in the salt or amine form.

Fuel Oil as Carriers for Ester

There has been considerable use of the fuel oils as carriers for the ester formulations of 2,4-D, particularly with airplane applications because oil can be effectively applied at much lower volumes per acre than water. In airplane operations there is a very distinct advantage in the use of oil since the number of acres they can cover on one flight determines to a large extent the cost of operation.

The use of fuel oils as carriers for the ester formulations must be handled with extreme care because oil is toxic or poisonous to cereals, although rates of one gallon per acre have not caused damage when applied accurately. Considerable damage to spring wheat has been noted in several of the northeastern Montana counties when oil was used as a carrier. Most, if not all, of the damage was due in a large part to poor distribution of the material, since the damage occurred in streaks through the field. 157

● WATER AS A CARRIER FOR 2, 4-D: In the more humid areas water has been found to be quite satisfactory as a carrier for 2,4-D, with relatively low gallonages, sometimes as low as 2 or 3 gallons. Wherever a low rate of evaporation makes it possible to obtain adequate coverage with 2 or 3 gallons of water, it may be more economical than the use of oil as a carrier. Water permits the use of either the amine or ester forms of 2, 4-D.

Water is less hazardous to crop plants than oil and usually costs less to obtain and transport to the flying field. On the other hand, oil may result in superior weed control where maximum wetting and leaf penetration are necessary. Also oil usually may be applied in lower volumes. Low Volume in oil vs. Large Volumes of Water: The idea of using low volume of oil instead of large water volume as a carrier for 2,4-D appeals to many operators. Early tests, 46, by mid-west operators found that 1 gallon of diesel oil No. 2 per acre gave adequate coverage. That gallonage has become the more or less standard carrier by many operators. Esters are being used almost exclusively in air-application where oil is used as the carrier.

● SUMMER OILS: Such materials are made from petroleum oils with unsaturated hydrocarbons removed. They are chemically inert and effective as wetting agents against summer stages of scale insets, mealy bugs, and spider mites. They are used in 1 or 2 percent solution. Their toxicity may be increased by adding nicotine, pyrethrum, or derris root extracts. They are unsafe on sugar maple, Japanese maple, beech butternut and black walnut. 71

Disadvantage of an Oil Solution: The *disadvantage* of an oil solution is in the fact that oil is very effective in burning *young foliage.* Where young tender foliage is involved, an oil-in-water emulsion is recommended. An oil-in-water emulsion is best when:

1. The temperature is very low.

2. Water is very scarce.

3. When the plants are full grown.

4. When foliage is young and tender.

5. The humidity is high.

● VOLUMES OF CARRIER NEEDED: The amount of carrier needed is that which is sufficient to give good coverage to the foliage. For ground spraying on dryland, 5 gallons or more of water per acre are recommended. Under irrigated conditions, or on dryland where susceptible crops may be injured by drift, a minimum of 20 gallons per acre is suggested because a high volume, low pressure spray will reduce the danger of damaging drifts. Tall, dense foliage will require higher volumes of carrier to obtain coverage than does a short, sparse growth.

DUSTS

Dusts are commercially available in varying percentages of the techinical chemical or active ingredient. The inert ingredients are there only to give bulk and dilution to the active ingredient. The inert ingredients are called carrier diluents.

Dust Carriers

Carriers most commonly used are:

hydrated lime	cheap flour	talc
ashes	bentonite	koalin
Cherokee clay	celite	pyrophyllite
fuller's earth	gypsum	calcium carbonate
silica	sulfur	calcium phospate
walnut shell flour	fine road dust	magnesium carbonate

Some carriers have special advantages for certain types of application. Important properties to consider in diluents are such things as: the acidity or the alkalinity, the particle fineness, the dustability, specific gravity, hardness, particle shape, adsorption or absorptive properties, compatibility, stability, cost, availability. Alkaline materials, such as hydrated lime, are used with nicotine dusts to liberate the nicotine but cannot be used with pyrethrum or rotenone dusts, the active principles of which are not stable in the presence of alkalies.

Diatomaceous earth, because of its very light weight, is used to give bulk and fluffiness to heavier materials. Bentonites are noted for their absorption and holding properties. Sulfur and borax which have some insecticidal and fungicidal activity of their own and which are relatively cheap materials are frequently utilized as diluents of more potent materials. Because of its absorptive properties Fuller's earth has widespread use as a carrier for the preparation dry dusts and wettable powders from liquid and semi-solid toxicants. Kaolin clay is material used extensively in formulating pesticides. Some types have exceptionally good wetting qualities.

SOLUTIONS

Solutions are homogeneous mixtures of different ionic or molecular species. 208 In a solution the different materials mix easily and remain in solution without agitation. Sugar dissolved in water is an example of a solution. This is in contrast to a suspension which requires constant agitation to prevent the active material from settling out.

To get the active chemical ingredient into solution is often a problem and requires the adding of a solvent. Solvents are described in later paragraphs. Solutions can be prepared with numerous materials such as: Mineral oils, kerosene or fuel oil and vegetable oils such as cotton seed oil, and industrial solvents. (Cyclohexanone can be used to speed the solution process.

Care must be used in the use of solutions to avoid burning foliage—some are inflammable and explosive. Some are poisonous in themselves and irritating to eyes, nose, throat, or skin. The use of masks, goggles, gloves and other protetive clothing is always wise as a precautionary measure.

Solubilizers are used to achieve solution in liquids in which normally the chemical by itself is unsoluble. For example, 2, 4-D and 2,4, 5-T are virtually insoluble in water. It, therefore, becomes necessary to formulate *soluble salts* which can be diluted to use concentration by adding water. 206

Solvents, Blending Agents

The liquid vehicle for a spray preparation must be cheap enough for the economical use of the product. Such vehicles therefore are limited chiefly to water and to petroleum fractions, sometimes carbon tetrachloride in the case of liquid fumigants which reqiure a carrier. Both toxicant and such additives as spreaders and emulsifiers should remain uniformly mixed with the vehicle until used, but not all desirable ingredients are soluble in the vehicle. Varying kinds and quantities of blending agents or "solubilizers" are frequently added to overcome this difficulty. These materials are mutual solvents of vehicle and toxicant or additive. Ethyl alcohol, isopropyl alcohol, and acetone are common water-soluble solvents used. Certain petroleum derivatives and various essential oils, as pine oil, and amphor sassafrassy, have been utilized in petroleum solutions. Sometimes more than one blending agent must be used to obtain a clear product. Mutual solvents for derris and cube extractives in petroleum include n-butyl phthalate, "Cardolite 627," and a number of other by-products and individual organic compounds.

SUSPENSIONS

Suspensions are often preferred to the emulsions for treatment of green foliage. It is a third form of spray preparation. This method involves using a solvent which dissolves in water. For example, DDT is placed in suspension by first dissolving the DDT in acetone or alcohol with a wetting agent then mixed with pyrophyllite, walnut shell dust or bentonite and allowed to dry. It is then reground into a fine powder to which the DDT adhers. The powder is then mixed with water to the desired strength. Water suspensions are particularly adapted for agricultural use as it does not burn foliage. Suspensions have the disadvantage of requiring continuous agitation. This applies to most wettable powders.

EMULSIONS

Emulsions are mixtures of immescible liquids, for example, oil and water. Almost any two liquids differ in density. Such mixtures tend to settle into layers unless constantly agitated. Emulsion stabilizers are agents which assist in keeping the materials from settling out in layers. 208

Insecticides may be obtained in the form of a *true solution* (active ingredient completely dispersed throughout the body of the liquid) or they may be obtained as an emulsion (varying particle size) or a wettable powder (active ingredient is incorporated in a wetting agent). Most emulsions are usually available in the concentrate form to be diluted in either *water* or *oil* as specified. Some emulsifying agents produce a relatively stable emulsion. Others produce what is known as a quick breaking or unstable type emulsion.

When applying emulsions to heavy vegetation it is possible to get greater penetration by increasing the drop size. The larger droplets will penetrate fartherest into the foliage. It should be remembered that in using emulsions the water may evaporate when sprayed from a high altitude when the humidity is low (dry air).

Some materials such as oil and water just would not mix and remain in suspension even with agitation unless an emulsifying agent is present. These agents are called emulsifiers. Potassium soaps and fish oil soaps have been used effectively for they are soft soap and therefore easy to handle. Fresh milk, condensed milk and flour have also been used as emulsifiers.

Emulsifiers may be divided into two classes: (1) those which form emulsions without the aid of heat and to which the name "cold mix" emulsions have been applied. Calcium caseinate, bordeaux mixture, and a number of colloidal clays belong to this class. A commercial form of calcium caseinate known as "Kayso" is probably the one most commonly used. (2) Those which require heating or boiling to emulsify the oil. Various soaps, of which fish oil soap is one of the best adapted, form this class. 195 Emulsions as a rule do not require agitation unless they are of the *quick break* type.

Oil-in-water emulsions have the *advantage* that they can be used on young tender foliage where straight oil as a carrier might result in extensive burning of the foliage. The disadvantage is that usually much larger volumes need to be carried to cover a given acreage. This, of course, results in increased cost of application. If there is any indication of foliage burning, lessen the rate of application.

Oil may be emulsified in water with the use of an agent such as soap. A common form of emulsion may be made by mixing ratio of 2 gallons of lubricating oil, one gallon of water and 2 pounds of cheap soap. This concentrate should be diluted with 100 gallons of water. When used on trees or shrubs it should be applied in the spring before foliage appears. Because of the technique required it is best not to attempt to prepare your own emulsions unless you are thoroughly familiar with the process.

Miscible Oils

A miscible oil is one in which the oil has been mixed with the emulsifier. In true miscible oil, such as usually manufactured by commercial companies, the stock oil is an oil solution of the emulsifier, more or less thoroughly mixed and containing 93 to 99 percent of oil As a rule, such miscible oils keep well, do not spoil on freezing, and do not settle out on standing. Miscible oils require care, however, when being diluted with water for spraying, a point often overlooked. In the preparation of sprays from miscible oils a *small amount of water* should be *added* to the oil and mixed until the combination becomes a whitish paste. Additional water is then added slowly, with constant stirring, until the paste becomes a creamy emulsion, after which the balance of the water may be added as rapidly as desired. With most of the miscible oils the pouring of the stock into a large amount of water may result in an oily mass that will not mix with water. The best type of miscible oils utilize fish oil soap and cresol as an emulsifier and such types mix most readily and thoroughly with water. 195

● HOW TO USE A MISCIBLE OIL: When adding water to miscible oil stock be careful to use the following process, otherwise you may get an oily mass that will not mix with water. (1) Add a small amount of water to the oil and mix until the combination becomes a whitish paste. (2) Add more water slowly with constant stirring until paste becomes a creamy emulsion. (3) Add the balance of water as rapidly as desired.

● JELLY TYPE EMULSION: The jelly type emulsion is a thick emulsion containing 80 to 85 per cent oil, nearly white in color, depending on the purity of the oil used. It must be ladled from wide-mouthed containers. The jelly type of emulsion is intermediate in stability but usually no difficulty is experienced in handling it. This material contains water and therefore must be *protected* from freezing. In order to mix the jelly emulsion in the syray tank, first add water until the agitator shaft is covered and then add the emulsion. Allow the agitator paddle to mix thoroughly the water and emulsion and then fill the tank with water. When used in combination sprays, it should first be mixed with an equal amount of water and stirred or beaten with a wire whip to an even, thin consistency. It may then be poured into the spray tank when partly full or full, as the directions require. 219

● FLOWABLE TYPE EMULSION: The flowable type emulsion also contains 80 to 85 percent oil and is similar in appearance to the jelly type except that it is not so thick and may be poured directly into the spray tank at the time indicated. Emulsions of this kind usually are more stable than other forms on the market and do not give as heavy a deposit of oil on the surface sprayed. When the flowable type is used in the summer as a foliage spray, however, it is preferable to stir in an equal amount of water before adding the emulsion to the spray tank. 219

● LUBRICATING—OIL EMULSIONS: Lubricating—oil emulsions are frequently used in the Pacific Northwest for controlling the San Jose scale, red spiders and leaf rollers. They may be obtained commercially in a form readily diluted with water or they may be prepared in the following proportions:

oil—100 gallons

ammonia (28 percent) 1 quart

casein (finely powdered) 3 pounds

water—33 gallons

1. Put the water into a tank with the agitator running.

2. Sift in the casein slowly.

3. As soon as the latter is dissolved add the oil about as fast as it will run from the drum. It is important to add the oil slowly as a reverse emulsion may result if added too rapidly. (A reverse emulsion will not mix with water).

4. Agitate for a few minutes then pump through a spray hose at about 250 pounds pressure into empty drums for storage.

Emulsions for dormant or summer use are prepared the same but different oils are used. Be sure that proper oils are used. For *dormant* spraying the oil should have a viscosity of 100 to 120 seconds saybolt with an unsulfonated residue of 50 to 70 percent. For summer spraying under most conditions the viscosity of the oil should be 65 to 75 seconds soybolt with an unsulfonated residue of at least 85 per cent.

Stabilizers

Stablizers are compounds having molecules that are polar at one end and non-polar at the other. When added to emulsion these molecules arrange themselves in such a manner as to keep the oil droplets from coalesing. When petroleum sodium sulfonate stablizers such as oronite wetting agent is added to an oil-water emulsion, the petroleum ends of the stabilizer molecules dissolve in the oil droplets and the sodium sulfonate (polar) ends dissolve in the water. The oil droplets assume like electrical charges and hence repel each other. This keeps them apart and they do not coalesce.

An emulsion stabilizer reduces the interfacial tension. This same virtue also tends to make the emulsion spread rapidly over the waxing surface of the foliage. 208

AEROSOLS

Aerosols are dispersions of the insecticide in solution in very fine particles. This method appears wasteful however the immediate result, not the residual effect, is the goal of this method. Aerosol can be sprayed from an airplane or it can be distributed through the use of a fog machine (the field counterpart of the well known aerosol bomb).

SPREADERS – STICKERS – PENETRANTS

Spreaders, wetting agents, and penetrants are materials used to insure better contact between a spray mixture and the sprayed surface. Substances that promote wetting are not usually good stickers, and often reduce the original deposit. Therefore, they are of more use with contact than with stomach posions. Soap is a good spreader but a poor sticker. It is not usually used with arsenical sprays because it tends to aid the formation of water soluble arsenic. Hard water interferes with its use due to the formation of insoluble calcium soaps. Many materials first used as base detergents in the textile industry are now offered for use as spreaders. These materials are of both acid and alkaline nature, and offer certain advantages over soap. Oils act as spreaders of toxicants dissolved in them.

Petroleum oil acts as a sticker as well as a spreader, and certain animal and vegetable oils, such as fish oils, cottonseed and soybean oils, are excellent adhesives. Casein, in the form of calcium caseinate or skim milk powder is chiefly a sticker but also to a certain extend a spreader. It is usually used at 0.5 to 1 pound per 100 gallons of spray. Wheat flour and soybean flour are good stickers. Triton B-1956 is a typical petroleum base spreader. Other commercial spreaders are graselli and dreft.

Wetting and Spreading

Fig. 13 represents the problem of wetting and spreading. When a droplet of water comes to rest on a waxey surface it does not wet. It tends to form a sphere because of its own *surface tension* or *skin*, such as seen at (a). The skin being under tension tends to pull the liquid into the smallest volume possible.

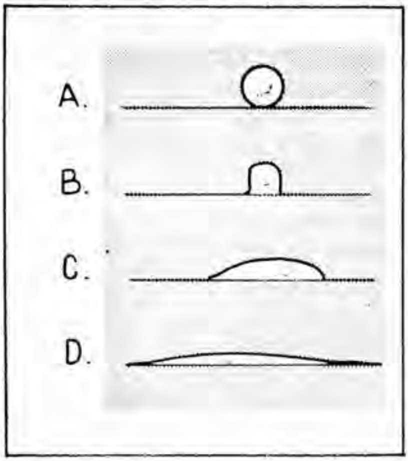


Fig. 13. Droplet effect with the use of spreaders and wetting agents.

When the liquid wets the surface on which it comes to rest other forces tend to pull the liquid out in a plane along the surface it has wetted. Wetting and spreading appear to be simultaneous, however, the wetting must always precede the spreading. There are three forces present in every wetting situation. There is the surface energy of the solid which tends to pull the liquid out into a thin film. Against this force acts the *skin* tension of the liquid drop and the interfacial tension.

If a liquid wets a surface but does not spread it will look something like (b). If wetting and spreading occur the drop will appear as (c) or (d) depending upon the extent to which the surface energy of the plant overcomes the skin tension and interfacial tension.

● WETTING AGENTS ON TYPES OF FOLIAGE: In applying any insecticide or herbicide consideration must be given to the type of foliage to which it is being applied. The texture of the plant will have an important effect on wetting and spreading properties of the emulsion, solution or suspension being applied. Here again the agent must be tried out on the desired plant to verify its effectiveness. If the interfacial (area between the insecticide and the plant surface) is lowered too much you will get run-off which is to be avoided. The most desirable material gives a maximum spreading with a minimum of run-off.

● TRIETHANOLAMINE soap is frequently used in a mixture with oil as a spreader-sticker for arsenicals. This material is marketed as spralastic. It is said to increase the deposit by as much as three or four times.

Soaps

When animal or plant fats and oils are treated with hot alkali, soaps are formed. These soaps consist of the fatty acids from the fats and oils combined with the sodium or patassium hydroxide of the alkali. Similarly, resin soaps may be formed. By first spreading certain petroleum products with strong sulfuric acid under specified conditions and then adding alkali, a number of compounds called "sulfonated petroleum soaps" are prepared. These various soaps all have valuable properties as emulsifying agents and wetting agents, which have been discussed. By themselves, soaps are sometimes used as insecticides against soft-bodied insects at the rate of 4 to 10 pounds per 100 gallons of water. Their greatest use, however, is with other insecticides, such as nicotine or nicotine and oil sprays.

Largely on account of lower cost, fish or whale-oil soaps have been used more than other kinds but powdered soaps are very convenient, and even laundry soap may be used if it is first dissolved in hot water.[60]

Soap is good as a wetting agent and spreads well but is of no value as a sticker since it washes off readily. It usually is unsafe for use with arsenicals and lime-sulfur but is excellent with nicotine compounds.[71]

● OIL SPRAY AS A STICKER AND SPREADER: Oil emulsions have their place both as spreader and as adhesive for homemade bordeaux mixture, various commercial copper compounds, rotenone root, and pyrethrin sprays. As a sticker for bordeaux mixture the combination may be mixed in the spray tank as follows: Just before beginning to spray, stir an equal amount of water in 1 quart of oil emulsion and pour into tank. If the bordeaux mixture is applied in the dormant season, any dormant oil emulsion may be used. If the bordeaux is used as a foliage spray in summer, a light or light-medium oil having a sulphonation test of 70 or above may be used.

The combination of oil with various commercial copper compounds serves as both a sticker-spreader and safener. A pint of the oil emulsion is sufficient if 4 pounds or less are used. If 5 to 8 pounds to 100 of copper compounds are used, a quart of the oil emulsion is necessary. The mixture should be made as follows: Place the required amount of the copper compound in a bucket and add sufficient water to make a thin slurry. Then stir in the oil emulsion and add the mixture to the spray tank filled with water. Apply immediately. 219

Stickers

A sticker is a material which acts as an agent in causing the chemical to adhere and not form a droplet which will run off the (sometimes very waxy) surface of the plant. Spreaders are needed and used in conjunction with stickers first to keep the stickers from causing the chemical particles in the spray tank to be drawn together and second to reduce the surface tension between the droplets and the plant surfaces.

● FLOCCULATION (SPLOTCH): When a spray material does not possess the proper amounts of spreader to go with the sticker spotching or flocculation occurs. The chemicals tend to be drawn together and large quantities collect in one area leaving adjacent areas uncovered.

● CASEIN: One of the first materials to be used as a spreader for the arsenicals was skim milk mixed with lime. Casein is now used in the form of calcium caseinate as a spreader and sticker at the rate of 1 to two pounds to 100 gallons of spray mixture. Casein by itself lowers the surface tension of water making it possible to spread the water over waxy plant surfaces. Hydrated lime acts as a sticker to prevent the chemicals running off resulting in loss of material.

● BLOOD ALBUMIN: Powdered blood albumin spreader used at the rate of 4 ounces to 100 gallons of water is one of the newer important spreaders coming into use.71

● FLOUR: Ordinary wheat flour is an excellent spreader and sticker. It is used at the rate of 2 to 4 pounds to 100 gallons of spray and should be mixed into a thin paste for putting in the spray tank. 71

● SOYBEAN: Soybean flour and wheat flour at the rate of one teaspoon per gallon of spray makes a good sticker. First, make a paste of desired amount and add to spray or sift slowly into the agitated liquid in the tank. These materials tend to cause the spray to adhere wherever they hit the plant. To get the material to creep over the surface of the plant giving thorough coverage a spreader must be added.

Hard and Soft Water

Water containing considerable quantities of calcium or magnesium compounds in solution is called *hard* water. If these elements are lacking but soluble compounds of sodium or potassium are present, it is called *saline*. The principal compounds present in hard water are calcium and magnesium sulfates, chlorides, and bicarbonates; and those in saline water are sodium and patassium sulfates, chlorides, carbonates, and bicarbonates. Combined hard and saline water occasionally occurs also. All such types of water give rise to difficulties with certain spray solutions.

Hard waters sometimes pose a problem by creating insoluble soap materials. The sulfonated alcohols can be used with hard water without causing insoluble soap particles. Sulfonated alcohols are useful as spreading and wetting agents. 71

Owing to the formation of insoluble lead compounds and the release of soluble arsenic, burning often results from the use of standard lead arsenate in such waters. Basic lead arsenate may usually be substituted. Sodium fluosilicate and cryolite (sodium fluoaluminate) in hard waters give rise to soluble fluoride with consequent danger to plants. Nicotine sprays activated with soap, found in certain formulas, are lessened in efficiency in hard water because the soap is removed as insoluble calcium or magnesium soaps, which are not alkaline enough to liberate nicotine. Similarly soap solutions alone are rendered useless and there is danger of plugging up the spray nozzle. Oil emulsions stabilized with soap become unstable in hard or very saline waters and may break.

Hard water may be softened by the use of washing soda, lye, or soap, or by passage through a commercial water-softening chamber. If washing soda or lye is used, the amount necessary must be ascertained by analysis of the water, for an excess will be as bad as the original water. Many commercial *water conditioners* usually adapted for use with particular insecticides are now available.

Much effort has been expended to find emulsifiers and spreading agents which are not affected by the quality of the spray water. Oil emulsions containing blood albumin or petroleum soaps are relatively unaffected. Insecticides made up with an excess of lime (as are bordeaux mixture, many commercial fluorine preparations, and lime-sulfur) may be used with almost any water. Lastly it should be mentioned that the use of dusts instead of sprays avoids the difficulty.60

Sequestering Agents

Sequestering or dispersing agents are required whenever 150 PPM (parts per millions) of water hardness exists. Sequestering agents are used to prevent precipitation of the 2,4-D slats of calcium and magnesium. Such precipitates will plug spray nozzles.

WARNING: The addition of sequestering agents changes the freezing point of concentrates and may also affect its resolubility characteristics. Tests should be made of all materials in which sequestering agents have been used to determine their freezing points and resolubility characteristics. 206

SAFENERS

Chemical mixtures may change materially under certain temperature and humidity conditions or with the lapse of time. For this reason air and ground applicators should consult with chemical experts when there is any doubt about the status of any chemical material. For this reason too they should always follow closely the directions printed on the chemical containers.

To prevent certain possible adverse results from chemicals a number of materials are added to formulations as *Safeners*. For example, lime is used extensively with arsenicals to neutralize the formation of *arsenic acid*. Arsenic acid would be injurious to plant foliage.

Commercial zinc-hydrate sold under the trade name *Safe-N-Lead* is a commercial product designed to give a minimum of arsenic acid when using the arsenicals. This material is compatible with blackleaf 155.

In any spray material in which arsenate of lead or copper sulfate is used casein acts to form a film around the particles of lead or copper preventing hydrolysis and thus reducing the amount of arsenic and sulfuric acid that might form. Casein is used frequently with oil products to prevent the formation of *free oil* which might be injurious to plants.

COMPATABILITY

Often it is desirable to combine a two chemical treatment such as a fungicide and insecticide. Some chemicals will mix — others will not.

When chemicals can be combined considerable savings can be made by combining 2 treatments into a single application. For example, according to Leary, Fishbein and Salter,[8] DDT can be mixed with commercial sodium fluoride, sodium fluosilicate, cryolite, paris green, calcium arsenate, rotenone, pyrethrum and lime sulfur. Nicotine, however, should not be mixed with DDT. Unless a combination is definitely known to be satisfactory it should not be used except experimentally. A professional chemist is usually the only reliable source for this information.[118]

Lead arsenate and lime-sulfur are frequently applied together, but in such cases each is less effective than when used alone. Lead arsenate may be used with rotenone, pyrethrum, nicotine, or bordeaux mixture.

Nicotine and pyrethrum may be used with the various stomach poisons, oils or soap. Rotenone may be mixed with the common stomach poisons or oils, but it is generally not advisable to mix it with soap or lime.[214]

A mixture of several chemicals used for pest control or their separate application to the same plant within a short interval of time may be (1) desirable, (2) usable, (3) undesirable, or (4) injurious as follows:

1. The components of such a mixture may have a benefical synergistic effect increasing the efficacy of some of the ingredients or decreasing some hazard involved in their use.

2. The components of their efficacy may be unaffected by such usage and simply give the additive effect of the separate application of each component. The sole reason for using such combinations is the economy of application.

3. The efficacy of one or more of the individual components may be somewhat lessened by such usage, but not sufficiently to prohibit altogether the use of such a combination.

4. Some mixtures may be definitely injurious to plants, or through chemical reaction may result in the complete destruction of the efficacy of some of the components.

Further complications arise from the fact that a certain mixture may be used on fruits or plants under optimum weather conditions in certain regions but not under adverse conditions. It may be used on certain plants but not on others. It may be satisfactory when mixed just prior to use but not be suitable for prolonged storage. It may be hazardous to plants in leaf, but suitable for application to dormant deciduous plants. It may be hazardous when applied as a spray but not as a dust. It may afford satisfactory control of the pests concerned, but cause unsightly spotting of fruit or foliage, or render spray residue removal too difficult. The components may not be usable in a combination spray but may be applied separately within a short time. Some materials might be compatible from a chemical standpoint, but are similar in effect and are therefore not used together.[118]

Combinations

Combination sprays or dusts fall into two classes. In the first class, two or more insecticides are used against the same insect with the idea that those which escape one ingredient will be killed by the other. An example is the use of oil and nicotine sprays against various kinds of aphids. The second class of combination sprays include those intended for use against two or more pests of different types; these may be diferent species of insects, different species of fungi, or both insects and fungi. An example is the use of bordeaux mixture with basic lead arsenate for simultaneous control of peach twig borer and brown rot of peaches. In both classes the question arises as to what materials may be used together. This is much more than merely a matter of whether a reaction occurs between the materials used.

Two types of incompatibility may be distinguished: (1) a harmful substance is formed or liberated with consequent injury to plants; and (2) a useful ingredient is removed and the effectiveness lessened. The difference in reaction of plants in dormant and in foliage condition must be considered, for mixtures extremely toxic during the summer may be entirely satisfactory during the winter. A practical factor which lessens the number of useful mixtures is the necessity that the correct times for application of each of the components must coincide at least fairly closely.

An important summary of both theoretical and practical data on compatibility of insecticides and fungicides is contained in the California State Department of Agriculture Special Publication 184 (listed in the bibliography). Everyone using spray materials in combination or close sequence should be familiar with this publication. [60]

Parathion may be used for mite control along with DDT for the oriental fruit moth or the codling moth. Care must be used to be sure that the chemicals you wish to combine are compatible. As an example of incompatibility when combining wettable sulfur with DDT to control mildew *do not use* parathion. Sometimes a chemical has a neutralizing effect or may even change the character of one or both materials. It will pay you when unfamiliar with a combination to make a long distance telephone call and consult an *authority* before mixing chemicals the compatibility of which you do not know.

● DDT CAN BE MIXED WITH OTHER INSECTICIDES: Experiment by competent investigators shows that DDT can be mixed with commercial sodium fluoride, sodium fluosilicate, cryolite, paris green, calcium arsenate and lead arsenate, rotenone, and pyrethrum. No catalytic activity toward decomposing the DDT occurred. Nicotine possibly cannot be mixed with DDT. Nicotine in experiments produced a reaction that should be checked under field conditions.[8] DDT can be mixed with commercial lime sulfur and 2,3-dichloro-1, 4 napthoquinone.[8]

● DDT CAN BE MIXED WITH SOME FERTILIZERS: Experiment shows that DDT will mix with: amonium sulfate, monomonium phosphate, ammoniated superphosphate, amonium nitrate, cyanamid, manure salts, potassium sulfate, uramon, dicalcium phosphate double superphosphate, sulphate of potash-magnesia, potassium chloride, sodium nitrate steamed bonemeal, and milorganite. Dolomitic limestone was the only fertilizer tested which showed catalytic action.[8]

Compatibility of Parathion

Investigation continues but at this time parathion appears compatible for use with the following materials:

1. DDT, DDD and methoxychlor WP and dust blends.
2. Benzene hexachloride WP and dust blends.
3. Toxaphene WP and dust blends.
4. Rotenone and pyrethrins.
5. Insoluble copper and zinc compounds.
6. Wettable and dusting sulfurs.
7. Insoluble metal salts of dithiocarbamic acids, including ferbam, ziram, and zineb WP and dust blends.
8. Organic mercury compounds, including Tag and Puratized.
9. Pyrophyllites, Fuller's earth.
10. Bentonites, Kaolinites, diatomaceous earth; providing pH is below 8.5[160]

Herbicides and Insecticides Combined

Herbicides can be mixed with insecticides and a saving effected in application under certain conditions. They must be compatible and both mix in water or oil in the same manner. Because timing is so important it would only be a coincident if it so happened that both applications came at the same time. Attempting to treat together usually results in either one or the other being applied at an improper time. Where insecticides are used with other materials make sure that they are compatible. For example, chlordane concentrates in combination with alkalines of any kind are not compatible.

Insecticides with Fungicides

DDT, when combined with sulfur has additional advantages in the control of mildew and certain fungus diseases. For example, when used on grapes it is effective controlling the grape leafhopper, grape leaf beetle, the cutworm and mildew. Zinc sulfate will not mix with lime sulfur and the use of zinc sulfate with oil may cause injury.

Methoxychlor as stated by the DuPont Company is compatible with most commonly used fungicides, such as wettable or dusting sulfurs, bordeaux mixture, the low solubility (or fixed) copper compounds, and the newer organic fungicides the dithiocarbamates.

NEVER COMPROMISE ON ACCURACY

PART SEVEN

CONTRACTUAL AGREEMENTS

Air-applicating business practices are gradually becoming standardized. There is still, however, wide variance in methods of contracting throughout the states. Business methods are discussed in an admittedly inconclusive manner at this time because of lack of uniformity and standardization. The Air Applicator Institute will publish prior to the 1952 season a volume dealing exclusively with the business methods of air-applicating.

Who Furnishes the Chemicals?

Some air-applicators prefer to furnish the chemicals for the job. They can realize a handsome profit from the sales. Other applicators prefer to have the owner furnish the chemical materials, thus avoiding the responsibility for the adequacy or quality of the chemical.

● WHO DETERMINES THE DOSAGE? If the grower furnishes the material, decides on the mixture and the dosage rate, the air-applicator then is liable only for a uniform and accurate dispersion of the material. These are questions which must be carefully discussed with the grower. It's best to have these agreements made a part of the work order or contract.

● GUARANTEES: The "satisfaction guaranteed" practice is used to a *limited* extent. This means that the air-applicator does not collect if the job does not get reasonable results. This method of getting business is usually practiced only by the larger operators who have professional entomologists and plant specialists on their staffs and then only when there is little doubt about the outcome.

At present, there are so many variables that most operators are reluctant to use this practice. As time goes on and air-applicating becomes a more exact science this practice undoubtedly will be more popular. At present about the best that can be guaranteed is the uniformity of coverage. Some states have laws requiring post examination of job with a report on results.

Liability

Who is responsible for damage which may occur to adjacent property or crops, the grower or the applicator? This question is discussed in Book Five of this series, Answers to Legal Questions.

Contracts

CONTRACTS should include such items as:

1. The location and acreage to be treated.
2. Approximate time of treatment.
3. Who furnishes the chemical and carriers.
4. Who furnishes the ground servicing personnel, equipment and transportation.
5. Who furnishes flagmen.
6. Who assumes the responsibility for dosage recommendation.
7. Time and method of payment.
8. Conditions of release from contract such as hail, grasshoppers, or water shortage which renders crop treating uneconomical.

Work Order Forms

WORK ORDER FORMS should contain such information as the following:

1. Name and address of the grower.
2. Location of the field to be treated.
3. Time of desired treatment.
4. Crop and pest.
5. Chemical-dosage and formulation.
6. Graphic layout of field and obstructions.
7. Graphic layout of adjoining obstructions.
8. Graphic layout of adjoining crops (susceptible crop areas in red)
9. Name of pilot assigned to job.
10. Weather at time of application (wind direction and velocity, temperature).

11. Crop conditions at time of application (moisture content of ground, crop height and stage)

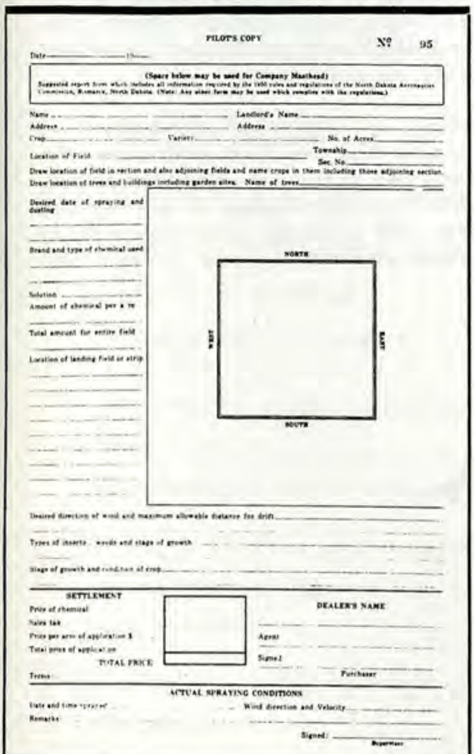
12. Miscellaneous conditions.

See Fig. 14 earlier in this part for sample work order.

Types of Complaints

Complaints of growers center around missed strips due to poor flagging or careless flying, improper swath computing or clogged nozzles. Leaf burning usually caused by too strong dosage, uneven swath distribution or swath over-lap.

● REDUCED YIELD: This is to be expected with many crops. The evaluation must be based on net gain based on what yield would have been had crop not been sprayed.


PILOT'S COPY No 95

Date ____ 19__

(Space below may be used for Company Masthead)
Suggested report form which includes all information required by the 1950 rules and regulations of the North Dakota Aeronautics Commission, Bismarck, North Dakota. (Note: Any other form may be used which complies with the regulations.)

Name ____ Landlord's Name ____
Address ____ Address ____
Crop ____ Variety ____ No. of Acres ____
Location of Field ____ Township ____ Sec. No. ____
Draw location of field in section and also adjoining fields and name crops in them including those adjoining section.
Draw location of trees and buildings including garden sites. Name of trees ____

Desired date of spraying and dusting ____
Brand and type of chemical used ____
Solution ____
Amount of chemical per acre ____
Total amount for entire field ____
Location of landing field or strip ____

NORTH
WEST
EAST
SOUTH

Desired direction of wind and maximum allowable distance for drift ____
Types of insects, weeds and stage of growth ____
Stage of growth and condition of crop ____

SETTLEMENT
Price of chemical
Sales tax
Price per acre of application $
Total price of application
TOTAL PRICE
Terms ____

DEALER'S NAME
____
Agent ____
Signed ____
Purchaser

ACTUAL SPRAYING CONDITIONS
Date and time sprayed ____ Wind direction and Velocity ____
Remarks ____
Signed: ____
Supervisor

Fig. 14. Courtesy North Dakota Aeronautics Commission.
Work Order Form.

● STERILITY: (wheat heads blank) sometimes due to spraying before stooling and after boot stages. Operator would not put on desired dosage — involves question of responsibility. Sometimes due to improper calibration or desire to save on chemical cost. Weeds died slowly — this is normal for 2,4-D and related chemicals.

● TYPICAL COMPLAINTS: Most of the complaints against air-applicator firms have centered around maintenance as follows: leakage of pumps, booms, valves and nozzles. Such leakage may injure susceptible crops over which the airplane is operated in ferrying or making turns off the treated field. Such leakage may also be hazardous to the pilot, should his clothing became saturated with chemicals.

The general mechanical condition of the airplane is a source of complaint by many pilots. Meeting FAA requirements for annual certification and 100 hour inspections are not sufficient. State aeronautical officials

may inspect planes in some states. The planes maintenance must meet their standards which are sometimes more rigid than FAA requirement. This is especially true of leakage, position shut-offs, calibration and those other features which are related to the dispersal equipment.

Overloading is a common complaint. FAA regulations now permit under the new Part 8, the setting of the gross load by the operator with the approval of a FAA representative. Loading is a matter of judgment and takes in many factors such as elevation, temperature, general conditions of power plant, gas load, weight and balance, etc. Some operators have placed minimum load limits on a sliding scale, taking these factors into consideration.

Air and Ground Operations

Air applicators who make a profession of weed and insect killing will frequently have occasion to deal with pest situations which cannot be treated from the air, such as small fields, corners of fields and areas where obstructions prevent safe air-operations.

A number of operators are building up substantial reputations as experts in the whole field of pest control. Many of these operators who are primarily air-applicators also own and operate ground equipment. With these trends in mind a portion of the information in this booklet is designed to serve this broader area and although not applicable to air treatment serves the air-applicators who also operate ground rigs.

TABLE OF CONTENTS

"METHODS OF AIR-APPLICATION"

The air-applicator must constantly keep in mind the basic concepts of chemical crop treatment. He must know that:

(a) Crops *stage* and *mature* differently in different geographical areas.

(b) That various species of the same plant *react* differently to the same chemical.

(c) That *growth conditions* materially affect toxicity.

(d) That *dry, warm weather* tends to toughen plant foliage.

(e) That the *carriers* used affect the effectiveness of the chemicals.

(f) That *timing* has much to do with results.

(g) That *temperature* has much to do with results.

(h) That the potential hazard of *drift* must always be kept in mind.

Fig. 15. Dr. Chamberlin and Hessig of the U.S.D.A. Forest Grove Experiment Station lay out slides across runway to test spray pattern and rate of deposit.

Air Applicator
Information Series

NOTE:—

This is but one of six volumes prepared to aid you in the techniques of air application.

Knowledge obtained from this series of information books is invaluable to every Air-Applicator. While each volume contains detailed matter pertinent to specific problems it is strongly advised that the complete set of six volumes be obtained so that the maximum benefit may be derived from the series.

SIX VOLUMES TO HELP YOU

1. **Knowing Agricultural Chemicals**
2. **Understanding Crops and Pests**
3. **How to Spray and Dust**
4. **Selecting Efficient Equipment**
5. **Answers to Legal Questions**
6. **Directory – Where to find it.**

The Air-Applicator Institute is always ready to try to assist you in the solution of your problems.

Write for a full list of available publications and services which the Air-Applicator Institute can supply.